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YUKON RIVER BASIN STUDY

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Yukon River Basin Study
Hydrology Report # 2

YUKON RIVER BASIN HYDROMETEOROLOGIC DATA NETWORK ASSESSMENT

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ABSTRACT

The various hydrometeorological data collection networks within the Yukon River basin have been assessed to determine their adequacy for providing baseline and site specific data. The networks considered in the assessment were the hydrometric networks operated by Water Survey of Canada (WSC) and the Yukon Region of the Department of Indian Affairs and Northern Development (DIAND), the meteorological network operated by the Atmospheric Environment Service (AES), and the snow course network operated by the British Columbia Ministry of Environment and DIAND. Study objectives were achieved by identifying data gaps and stations which are redundant or otherwise deficient in terms of location or instrumentation.

Both qualitative and quantitative techniques were used in assessing the adequacy of the data collection networks. The qualitative approach included a subjective evaluation of the spatial distribution of the respective networks. Present and future site specific requirements were assessed through the consideration of existing and potential major developments which included mining and hydroelectric developments, linear facilities and recreational uses. Previous studies were reviewed, as well as the policies and mandates of the respective agencies, and the history of network development in the basin. Data users and representatives of the various data collection agencies were canvassed for input by means of a questionnaire, telephone conversations, and follow up meetings.

The quantitative approach consisted of a statistical evaluation based on a regionalization procedure. This was carried out on the WSC hydrometric network only. The basin was delineated into regions of homogeneous hydrologic response. A correlation analysis was performed on all stations within the established regions with the intent of identifying pairs of stations which are highly interrelated.

Specific recommendations have been made to satisfy the identified deficiencies. These are summarized in a tabular form.

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1 Sample Data User Questionnaire

1.0 INTRODUCTION

Accelerating development and the associated population growth is increasing the demand for hydrometeorological data. This information is required for the planning, design and operation of projects, and daily activities of much of the world's population. This data is required for weather forecasting purposes to provide information for aviation, shipping and other forms of transportation. It is used for the design of hydraulic structures which include hydroelectric developments, stream crossings, flood control projects, and water supply systems. In addition, this data is also used for reservoir operation, flood and drought forecasting, and irrigation purposes. These activities depend upon the collection and accurate interpretation of basic observational data. The temporal and spatial distribution of data sampling is a function of the particular elements of interest with respect to their variability in time and space, the specific data use, the desired degree of accuracy, and economic considerations.

Historically, hydrometeorological data was collected for specific operational reasons. More recently, the utility of this information for planning and design purposes resulted in the establishment of data collection a short time in advance of a proposed development. It has become evident in the last decade, however, that relatively long term information is required for accurate planning and design. This has led to the concept of a baseline network which as a basic objective attempts to provide long term planning and design information for any given point within a region of interest. This is achieved by optimally spacing component stations in such a way as to facilitate the transfer of information to ungauged areas.

In addition, information is also required as before for site specific purposes for current operational needs or to provide information for imminent developments.

This report represents the product of a study carried out to assess the adequacy of the various hydrometeorological data collection networks within the Yukon River basin located in Yukon Territory and northern British Columbia.

1.1 Objectives

The overall objectives of the study were to evaluate the various hydrometeorological data collection networks within the Yukon River basin. The networks considered in the assessment were the hydrometric networks operated by

Water Survey of Canada (WSC) and the Yukon Region of the Department of Indian Affairs and Northern Development (DIAND), the meteorological network operated by the Atmospheric Environment Service (AES), and the snow course network operated by the British Columbia Ministry of Environment and DIAND. The adequacy of these networks was assessed with respect to satisfying both baseline and site specific requirements. Ideally, a baseline network will provide areal coverage for the entire basin regardless of the level of development and provide the basis for transferring planning and design information from a gauged area to any point within a region of interest. A site specific network is required to fulfill current operational needs and to provide information for proposed developments. These objectives were accomplished by identifying both data gaps in the existing networks and stations which are thought to be either redundant or otherwise deficient in terms of either location or instrumentation. Specific recommendations have been made to satisfy the identified deficiencies.

1.2 Methodology

Both qualitative and quantitative techniques were used in assessing the adequacy of the data collection networks. The qualitative approach included a subjective evaluation of spatial distribution of the respective networks. Present and future site specific requirements were assessed through the consideration of existing and potential major developments which included mining and hydroelectric developments, linear facilities and recreational uses. Previous studies were reviewed, as well as the policies and mandates of the respective agencies, and the history of network development in the basin. Data users were canvassed for input by means of a questionnaire and telephone conversations. Finally, meetings were held with key representatives of the various data collection agencies and user groups.

The quantitative approach consisted of a statistical evaluation based on a regionalization procedure. Due to limitations associated with the particular data types this was carried out on the hydrometric network operated by WSC only. An intermediate objective was to delineate the basin into regions of homogeneous hydrologic responses. A cluster analysis was initially carried out using relatively long term stations to define rudimentary groupings. Three hydrologic regions emerged, representing the St. Elias Mountains, the Coast Mountains, and Interior

Yukon. Too few data exist in the northern and eastern portions of the basin for statistical definition; therefore these were included with the Interior region.

Multiple discriminant analysis was used to refine these zones by amending or verifying the boundaries. The distinction between the two mountain zones became less apparent and these were combined, yielding two hydrologic regions. A correlation analysis was performed on all stations within the established regions with the intent of identifying pairs of stations which are highly interrelated. The summarized analysis forms the basis for specific recommendations to satisfy identified deficiencies.

1.3 Yukon River Basin Description

The Yukon River is the fifth largest river by volume in North America. Draining northern British Columbia, Yukon and Alaska, it has an area of 829,000 square kilometers and is approximately 2,900 kilometers long (Figure 1). The study basin in Canada has an area of 287,000 square kilometers and a river length of 1,030 kilometers from its source at Marsh Lake to the international boundary downstream of Dawson.

The basin is made up of an eroded plain bounded by the St. Elias and Coast Mountains to the southwest, the Ogilivie Mountains to the north, and the Selwyn Mountains to the east. The maximum elevations occur in the St. Elias Mountains, which contains the 6,050 meter high Mount Logan, the highest peak in Canada.

The Yukon Plateau is separated into two subregions by the Pelly Mountains. The basin contains two major trenches, the Tintina Trench which is occupied in turn by the Pelly, Stewart and Yukon Rivers, and the Shakwak Valley, which contains Kluane Lake and River (Bostock, 1948). The Yukon River and its major tributaries, the Stewart, Pelly, Teslin and White Rivers, flow generally in a northwest direction. The present drainage developed during the late miocene period when the St. Elias and Coast Mountains rose unevenly around the the interior portion of the region, entrenching the present stream network (Tempelman-Kluit, 1980). Prior to that period the river took a more favourable southwesterly course directly to the Pacific Ocean.

The basin is within the Boreal forest subregion which is characterized by spruce, pine and poplar in the lower elevations with some alpine fir at higher elevations and tundra above the treeline, which occurs between the elevations of 1,050 meters in the west and north and 1,500 meters in the south and east (Oswald

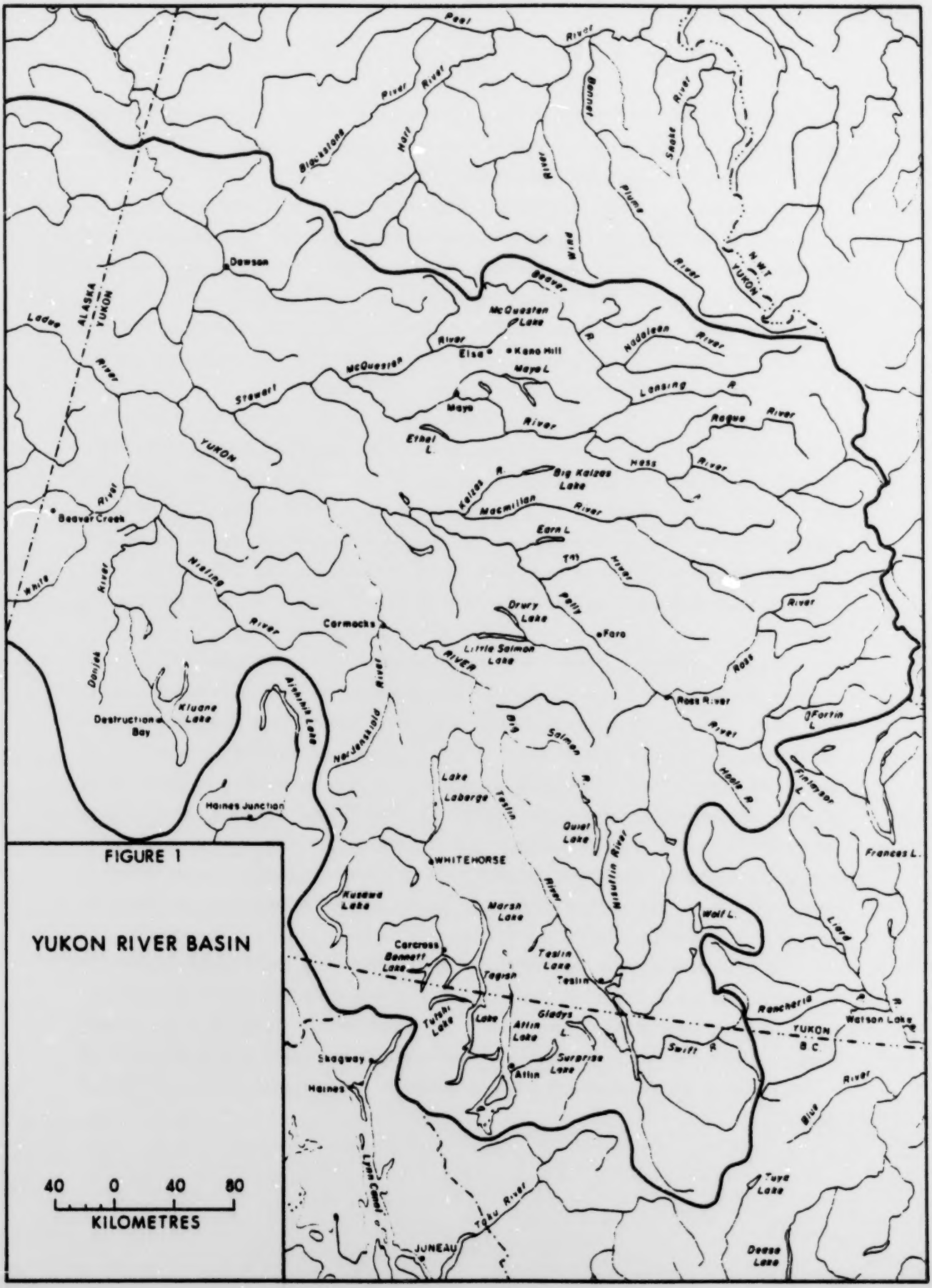


FIGURE 1

YUKON RIVER BASIN

40 0 40 80

KILOMETRES

and Senyck, 1976). The basin lies within the area of discontinuous permafrost, which limits ground water recharge and subsequently affects the hydrologic response of parts of the basin (French and Heginbottom, 1983).

The basin has a sub-Arctic continental climate which is characterized by a large annual variation in temperature, low relative humidity and relatively low precipitation. Mean annual temperatures range from near zero in the south to -7°C in the interior. July is the warmest month with a monthly mean of 13 to 16°C in the lower elevations. January is the coldest month with mean temperatures between -15 and -34°C. The Arctic inversion is common during the winter months when air temperature increases with elevation (Wahl, 1983).

Precipitation within the basin is generally low, though portions of the St. Elias and Coast Mountains have annual precipitation amounts of 1,000 to 3,500 mm. Immediately to the east of this barrier the upper Yukon basin lies in a rainshadow with annual precipitation amounts in the order of 250 mm. Precipitation again increases to the east with annual amounts in the Pelly-Cassiar Mountains ranging from 500 to 700 mm. To the east, Ross River receives less than 300 mm per year, while the Mackenzie and Ogilvie Mountains to the east and north again receive 500 to 700 mm.

Runoff events in the basin are characterized by peak flows in the spring or summer, primarily due to snowmelt and glacial inputs. In the southwest portion of the basin, streams which drain the St. Elias and Coast Mountains experience a rapid increase in discharge during the early summer in response to snowmelt at lower elevations. Flow increases in magnitude to a peak in the late summer due to glacier melt at higher elevations. Generally the streams draining the St. Elias Mountains exhibit a flashier response due to temperature and precipitation inputs during the summer. The Coast Mountains have smaller glacierized areas which in combination with the natural regulation provided by the lake system, tends to remove this variability.

Streams which drain the remainder of the basin are characterized primarily by a rapid rise in discharge in the spring due to snowmelt inputs. Peaks generally occur in June, after which time summer rains maintain high flows for a few weeks. Smaller systems within both regions are susceptible to peak flows in response to rainfall inputs, while intermediate sized basins may experience secondary rainfall peaks.

Streamflow decreases to a minimum in March or April, though ground water inputs generally maintain winter flows in all but the smallest streams. The Yukon River and most tributaries are generally ice covered from late October to early May.

1.31 Yukon River Main Stem

The main channel of the Yukon River originates at the outlet of Marsh Lake, which is the first of a series of interconnected headwater lakes draining portions of the Coast Mountains on the west, and the Teslin Plateau on the east. The uppermost system, Atlin Lake, with a lake area of 575 square kilometers, flows westward into Tagish Lake, which is a component of the Marsh-Tagish-Bennett system with a total surface area of 570 square kilometers. The river generally has a northeast heading, traversing the Teslin Plateau into the 200 square kilometer Lake Laberge. From the outlet of Lake Laberge it traverses the Lewes Plateau, skirting the Dawson Range where it enters the Klondike Plateau (Bostock, 1948). Downstream of Dawson it becomes entrenched in the Tintina Trench for the remainder of the distance to the international boundary. From south to north the topography is characterized by a series of high, partly disected tablelands which evolves into a broad irregular depression north of Lake Laberge. North of the Dawson Range the area is characterized by a series of narrow valleys separated by uniform ridges, the remnants of an old erosion surface. Elevations range from approximately 2,700 meters in the Coast Mountains to 268 meters at the international boundary.

The headwater areas of the Coast Mountains are dominated by alpine tundra; the sub alpine with shrub birch-willow with white spruce at lower elevations and spruce-aspen at warmer sites (Oswald and Senyk, 1977). Alpine fir and pine are absent from this area. The tree line is located at a range of elevations of 1,050 meters to 1,200 meters. A portion of the lake system and the lower river to a point midway between Lake Laberge and Pelly River are in an area dominated by white spruce and pine forests, with aspen in dryer locations and alpine fir at higher locations. The river then traverses areas of black and white spruce and pine with aspen in warmer locations, followed by predominantly open spruce with some birch at lower elevations. From the White River to the international boundary white and black spruce dominates with some aspen at drier sites and poplar in some floodplain areas.

Mean annual temperatures generally decrease, progressing downsteam. Higher temperatures in the south are primarily due to the moderating influence of the pacific air masses which occasionally are able to cross the barriers imposed by the St. Elias and Coast Mountains. Mean annual temperatures vary from approximately $-1^{o}C$ at Whitehorse to $-4^{o}C$ at Carmacks, $-4.5^{o}C$ at Fort Selkirk and $-5^{o}C$ at Dawson. The Yukon River generally parallels the 300 mm isohyet of mean annual precipitation (Wahl, 1983). Progressing downstream, 305 mm have been recorded at Atlin and 250 mm at Carcross, which is in a rain shadow of the Coast Mountains. Leaving the rain shadow area precipitation increases with 270 mm recorded at Whitehorse and Carmacks, 295 mm at Fort Selkirk, and 315 mm at Dawson.

The streamflow regime evolves progressing downstream from predominantly late summer peaks at Whitehorse and above Frank Creek in response to glacial inputs from the Coast Mountains with a secondary snowmelt peak in June. At Carmacks and at the station above the White River the peak occurs in June or July in response to the additional earlier snowmelt events provided by the tributary streams, the primary ones being the Teslin and the Pelly. Peak flows at Stewart River and at Dawson occur in June, the timing being advanced with progressively greater snowmelt inputs earlier in the season. Low flows generally occur in March or April prior to the spring freshet. The annual hydrograph for these stations are presented in Figures 2 and 3. Unit discharge statistics generally decrease progressing downstream as indicated in Table 1.

TABLE 1 YUKON RIVER MAIN STEM RUNOFF STATISTICS

NUMBER	NAME	DRAINAGE AREA (km^2)	UNIT MEAN ANNUAL DAILY DISCHARGE ($m^3/sec/km^2$)			ANNUAL RUNOFF (cm)
			MAX.	MEAN	MIN.	
09AB001	Yukon River at Whitehorse	19 400	.026	.012	.0038	38
09AB009	Yukon River above Frank Creek	30 800	.022	.011	.0040	35
09AH001	Yukon River at Carmacks	81 800	.024	.0086	.0028	27
09CD001	Yukon River above White River	150 000	.025	.0078	.0020	25
09EB002	Yukon River at Stewart River	251 000	.030	.0095	.0016	30
09EB001	Yukon River at Dawson	264 000	.028	.0084	.0018	26

FIGURE 2

HISTORICAL MEAN MONTHLY DISCHARGE

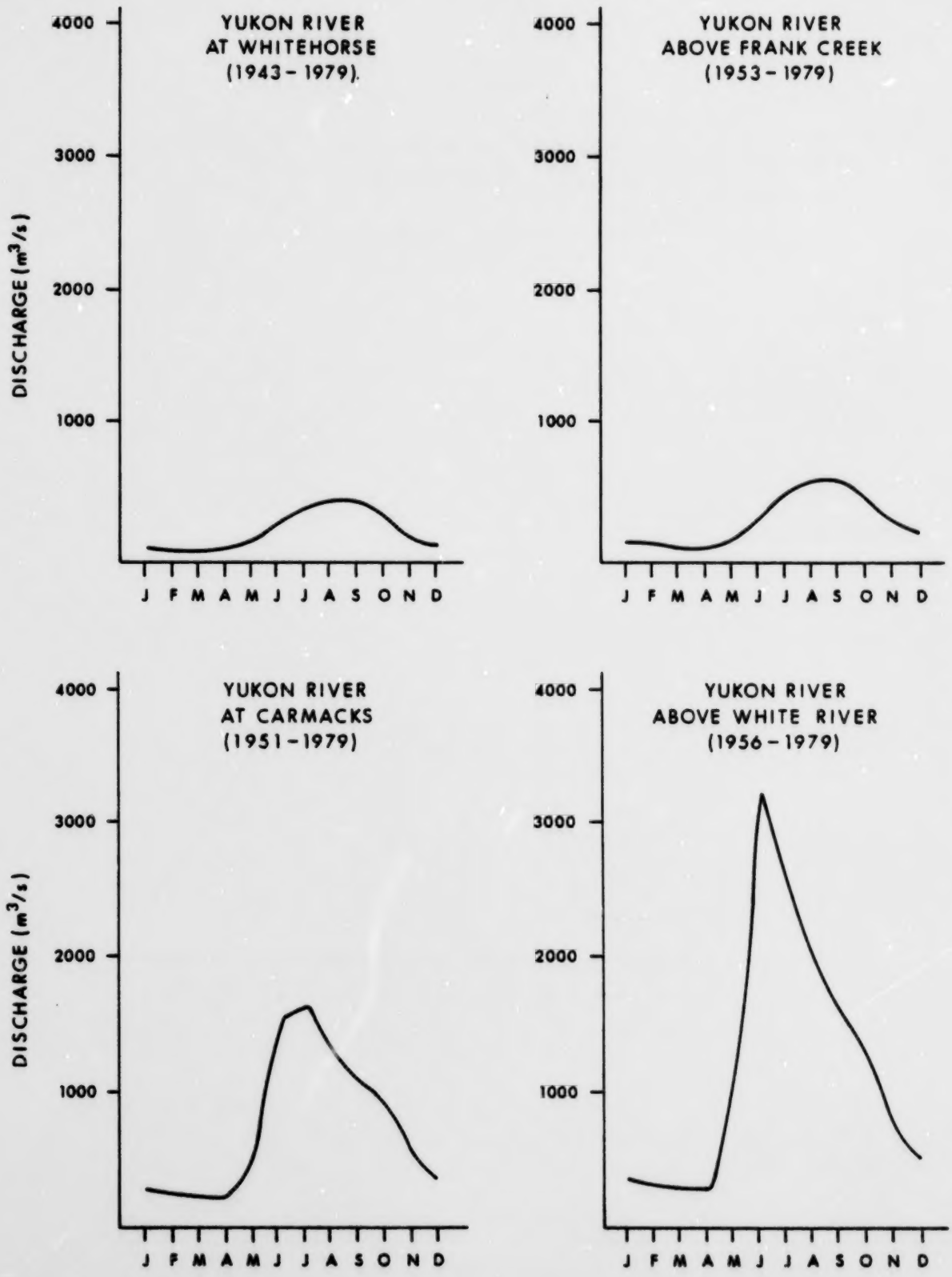
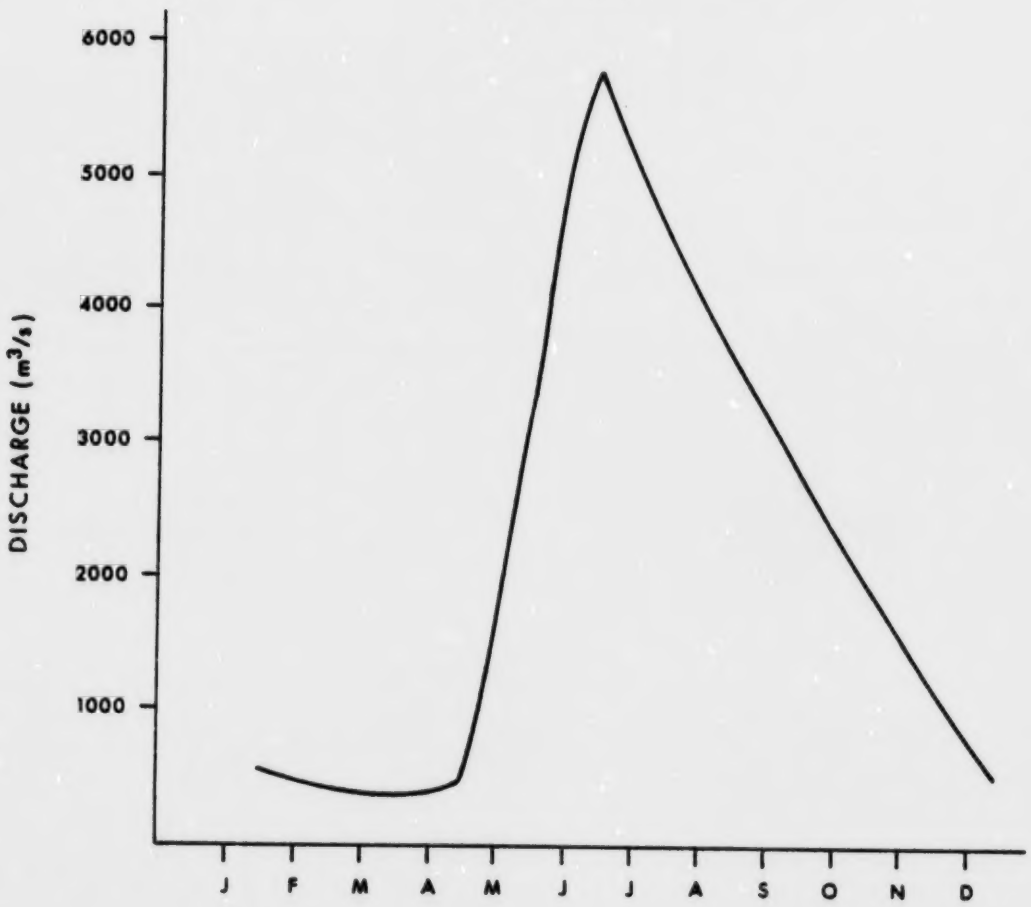


FIGURE 3

HISTORICAL MEAN MONTHLY DISCHARGE

YUKON RIVER AT DAWSON
(1951 - 1979)



This is due to the inverse relationship between unit discharge and drainage area. For comparison purposes runoff statistics for upper Yukon headwater drainages are presented in Table 2.

TABLE 2 UPPER YUKON RIVER RUNOFF STATISTICS

NUMBER	NAME	DRAINAGE AREA (km^2)	UNIT MEAN ANNUAL DAILY DISCHARGE ($m^3/sec/km^2$) MAX.	MEAN	MIN.	ANNUAL RUNOFF (cm)
09AA010	Lindeman Creek near Bennett	240	.239	.0414	.0023	131
09AA015	Wann River near Atlin	269	.131	.0259	.0035	82
09AA008	Pine Creek near Atlin	697	.025	.0074	.0018	23
09AA014	Fantail R. at outlet of Fantail L.	717	.153	.0307	.0022	97
09AA013	Tutshi R. at outlet of Tutshi L.	829	.079	.0197	.0038	62
09AA009	Watson River near Carcross	1150	.020	.0044	.0010	14
09AA007	Lubbock River near Atlin	1770	.005	.0026	.0012	8
09AA006	Atlin River near Atlin	6810	.033	.0137	.0039	43

Considerable variability is exhibited by these, in part due to the relatively small drainage areas. The greatest disparity, however, is between basins draining the Coast Mountains and the Yukon Plateau.

1.32 Teslin River Basin

From its headwaters in the Stikine Plateau in northern British Columbia the Teslin River flows in a northwesterly direction into Teslin Lake, which represents the beginning of the Yukon Plateau. Draining an area of 35,500 square kilometers, this includes Teslin Lake which is approximately 95 kilometers in length. The Teslin enters the Yukon River approximately 50 kilometers downstream of Lake Laberge. With elevations ranging from 840 meters at its headwaters to 595 meters at the mouth it flows through the Teslin Plateau, a subunit of the Yukon Plateau. The Teslin Plateau is an elevated area consisting of high and poorly disected tablelands separated by a network of valleys.

Vegetation consists primarily of spruce and lodgepole pine, with aspen in some drier areas and alpine fir at higher elevations. The tree line in this basin is located at 1,200 to 1,350 meters. Mean annual temperature is approximately -1°C, relatively warm, due to the coastal influence. Mean annual precipitation ranges from less than 250 mm to 325 mm at Johnsons Crossing.

The streamflow regime is characterized by snowmelt peaks in June and low flows in March and April. A certain degree of natural regulation is afforded by Teslin Lake. Though the Teslin River's annual cycle is similar to the Pelly and Stewart, extreme flows are modified. The hydrograph for the Teslin River station near Whitehorse (approximately 10 kilometers from the mouth with a drainage area of 36,500 square kilometers) is presented in Figure 4 and basin runoff statistics in Table 3.

TABLE 3 TESLIN RIVER RUNOFF STATISTICS

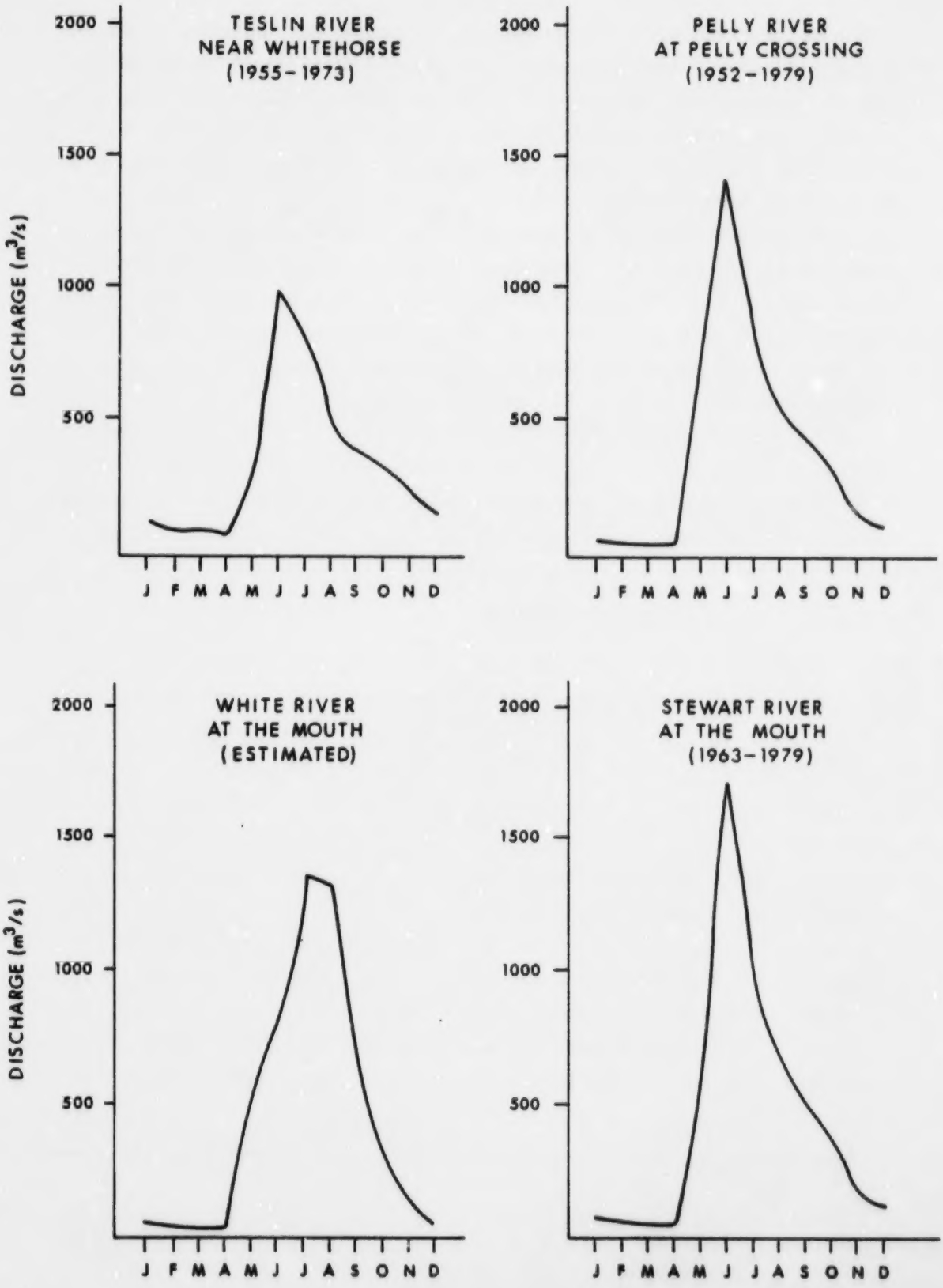
NUMBER	NAME	DRAINAGE AREA (km^2)	UNIT MEAN ANNUAL DAILY DISCHARGE ($m^3/sec/km^2$)			ANNUAL RUNOFF (cm)
			MAX.	MEAN	MIN.	
09AE004	Gladys River at Gladys Lake outlet	1 910	.031	.0079	.0018	25
09AE003	Swift River near Swift River	3 320	.074	.0144	.0028	45
09AG001	Big Salmon River near Carmacks	6 760	.046	.0100	.0023	32
09AE001	Teslin River near Teslin	30 300	.035	.0100	.0022	32
09AF001	Teslin River near Whitehorse	36 500	.031	.0091	.0020	29

1.33 Pelly River Basin

The Pelly River basin, with an area of 50,000 square kilometers, drains the eastern portion of the Yukon River basin. From its headquarters in the Selwyn Mountains it traverses the Pelly Plateau before entering the Tintina Trench, which

FIGURE 4

HISTORICAL MEAN MONTHLY DISCHARGE



it follows for approximately 250 kilometers in a northwesterly direction. It assumes a westerly heading, travelling across the Lewes Plateau to its mouth at Fort Selkirk. Its principal tributaries, the Ross and Macmillan Rivers, drain the Pelly Plateau, which consists primarily of rolling uplands, and the Macmillan Plateau, which consists of higher elevation broken uplands. Elevations range from 2,700 meters to 435 meters at the mouth.

Black and white spruce dominate the upper elevations of the basin below the treeline, which is located at 1,350 to 1,500 meters. Lower elevations consist of spruce, aspen, birch and pine, with alpine fir in the sub alpine. Mean annual temperatures range from approximately -9°C in the eastern uplands to -4°C near the mouth. Mean annual precipitation ranges from approximately 600 mm in the higher elevations to 290 mm at Fort Selkirk.

The streamflow regime is characterized by peak flows occurring in June in response to snowmelt and minimum flows in March. The annual hydrograph for Pelly River at Pelly Crossing (40 kilometers upstream from the mouth with an area of 49,000 square kilometers) is presented in Figure 4 and runoff statistics in Table 4.

TABLE 4 PELLY RIVER RUNOFF STATISTICS

NUMBER	NAME	DRAINAGE AREA (km^2)	UNIT MEAN ANNUAL DAILY DISCHARGE ($m^3/sec/km^2$)			ANNUAL RUNOFF (cm)
			MAX.	MEAN	MIN.	
09BC003	Rose Creek below Faro Creek	208	.0745	.0113	.0009	37
09BB001	South Macmillan River at km 401, Canol Road	997	.1087	.0198	.0012	62
09BA001	Ross River at Ross River	7 250	.058	.0092	.0009	29
09BC002	Pelly River at Ross River	18 400	.059	.0102	.0016	32
09BC004	Pelly River below Vangorda Creek	22 100	.048	.0092	.0008	29
09BC001	Pelly River at Pelly Crossing	49 000	.042	.0080	.0020	25

1.34 Stewart River Basin

The Stewart River basin, with a drainage of 51,000 square kilometers, drains the northeastern portion of the Yukon River basin. Elevations of the basin range from 3,000 meters at its headwaters in the Selwyn Mountains to 356 meters at its mouth, approximately 90 kilometers upstream of Dawson. Flowing in an easterly direction, the upper reaches drain the Wernecke and Hess Mountains on the northern and southern boundary areas of the basin respectively. The middle and lower reaches traverse the disected upland Stewart and Klondike Plateaus respectively, which are separated by the Tintina Trench.

Spruce and pine forests dominate the upper basin with alpine fir at treeline elevations, which varies from 1,350 to 1,500 meters. Black spruce dominates the lower elevations, with aspen, birch and poplar in areas free of permafrost or following forest fires. Spruce and deciduous trees occur in the major valley bottoms. Mean annual temperature ranges from approximately -9°C in the headwater areas to -4°C near the mouth. Mean annual precipitation ranges from 600 mm in the Selwyn Mountains to 300 mm in the lower elevation plateau areas.

The streamflow regime is characterized with peak flows occurring in June, primarily in response to snowmelt inputs. Minimum flows generally occur in March. The annual hydrograph for the Stewart River at the mouth is presented in Figure 4 and runoff statistics for the basin in Table 5.

TABLE 5 STEWART RIVER RUNOFF STATISTICS

NUMBER	NAME	DRAINAGE AREA (km^2)	UNIT MEAN ANNUAL DAILY DISCHARGE ($m^3/sec/km^2$)			ANNUAL RUNOFF (cm)
			MAX.	MEAN	MIN.	
09DA001	Hess River above Emerald Creek	4 840	.0968	.0147	.0011	46
09DD004	McQueston River near the mouth	2 870	.0655	.0142	.0020	45
09DC003	Stewart River above Fraser Falls	30 600	.0554	.0112	.0012	35
09DC002	Stewart River at Mayo	31 600	.073	.0117	.0009	37
09DD002	Stewart River at Stewart Crossing	35 000	.070	.0118	.0023	37
09DD003	Stewart River at the mouth	51 000	.048	.0090	.0012	28

1.35 White River Basin

Originating in the St. Elias Mountains, the White River, with an area of 38,000 square kilometers, drains the southwest portion of the Yukon River basin. Flowing generally in a northeasterly direction, it crosses the Kluane Ranges, which consist of a series of short, distinct ranges which form a narrow front ridge to the St. Elias Mountains. From there it crosses the Shakwak Valley which contains Kluane Lake and enters the Kluane Plateau, which represents the continuation of the Coast Mountains containing rugged upland surfaces such as the Nisling and Ruby Ranges and great rolling depressions, the largest being the Wellesley Basin which is filled with numerous kettle lakes. It then enters the Klondike Plateau, which is made up of a series of smooth ridges, remnants of an old uplifted erosion surface, disected by a series of deep narrow valleys. The principal tributary, the Donjek, drains the Kluane and Ruby Ranges, while a secondary tributary, the Nisling, drains the Nisling and Dawson Ranges. Elevations range from the 5,230 meter Mount Lucania, which represents the highest elevation in the Yukon River basin, to 363 meters at the mouth. Though Mount Logan, the highest peak in North America, is outside the basin, several other peaks reach 3,000 to 4,000 meters while elevations of the interior ranges are 1,800 to 2,100 meters.

The St. Elias Mountains contain extensive snow and ice fields, while the lower elevations are vegetated with spruce and some aspen in warmer areas. Treeline elevation is located at 1,050 meters. The Kluane and Ruby Ranges are dominated by spruce, with some birch and aspen and infrequent pine. Treeline elevation is at 1,200 meters. The Kluane and Dawson Plateaus are dominated by spruce and birch, with some aspen in drier areas. The Wellesley Depression consists largely of a black spruce bog while the major river valleys of the area contain poplar. Mean annual temperature ranges from approximately -13°C in the divide area of the St. Elias Mountains to -6°C reported for Snag. Though precipitation in portions of the St. Elias mountains is as high 2,000 mm annually, only a portion of this is able to breach the barrier imposed by the mountain range. Mean annual precipitation ranges from approximately 550 mm at the divide to 300 mm at the eastern boundary area.

Hydrologic response is characterized by peak flows occurring in July or August, primarily in response to glacial inputs. Unlike streams draining the eastern portion of the Yukon River basin, low flows occur in January or February and gradually increase to a secondary snowmelt peak in June. Though there is an

upstream hydrometric station, none is located near the mouth. The annual hydrograph for the White River near the mouth in Figure 4 has been estimated by subtraction. Runoff statistics are presented in Table 6.

TABLE 6 WHITE RIVER RUNOFF STATISTICS

NUMBER	NAME	DRAINAGE AREA (km^2)	UNIT MEAN ANNUAL DAILY DISCHARGE ($m^3/sec/km^2$)			ANNUAL RUNOFF (cm)
			MAX.	MEAN	MIN.	
09CA002	Kluane River at outlet of Kluane Lake	4 950	.053	.0147	.0017	46
09CA003	Donjek River below Kluane River	12 400	.0545	.0190	.0027	60
09CB001	White River at km 1882 Alaska Highway	6 240	.1215	.0180	.0020	57

1.4 Hydrometeorologic Data Requirements

Hydrometeorological data is required for many purposes which may generally be categorized as baseline or site specific. In certain cases an individual component station may serve both needs. Historically hydrometeorologic stations were established to meet specific operational purposes, while more recently it has become evident that relatively long term data is required for accurate and economical planning and design. During the past decade this knowledge has led to the concept of the baseline network.

Applications may be classified by use for inventory, planning, design, forecasting and monitoring purposes (Halliday, 1983). Though all of these categories may provide information for both baseline and site specific requirements the former three most adequately provide the basis for a baseline network.

A station established to provide inventory information generally operates at a regional level providing data to define the spatial distribution of the element of concern. These stations usually fit into a larger national framework. Stations established for planning and design purposes may serve the needs of a proposed development and take into consideration a specific planning horizon. The information provided by these stations will better define the regional distribution of the element of concern.

Stations established for forecasting and monitoring purposes may be referred to as operational stations. These are required to meet specific project needs whether at a local or regional scale, and for legal surveillance purposes.

1.41 Baseline Requirements

The primary purpose of a baseline network is to provide long term planning and design information on a regional basis. The overall objectives of this network is to provide the basis for transferring information to any ungauged location within the Yukon River basin without regard to the level of development.

1.42 Site Specific Requirements

Both proposed and existing developments may have site specific hydrometeorological data requirements. Proposed developments require data for planning and design purposes. In some cases baseline data may suffice where no site specific information is available; however, often when design criteria are needed for a site which is not entirely representative of the surrounding area in terms of hydrological or meteorological characteristics the area must be instrumented and the desired data collected prior to development. Nearby long term baseline information may be used to supplement this data by providing the ability to extend records and estimate missing values. Sometimes a few miscellaneous observations will suffice if only rudimentary estimates are required. However, in order that a representative sample set be obtained, a relatively long time period is required. Generally, a ten year record length represents the lower limit of acceptability for statistical purposes.

The recently commissioned Aishihik hydroelectric plant serves as an example to illustrate the need for site specific information. Feasibility studies for this development were carried out with very little monitoring to define the inputs to

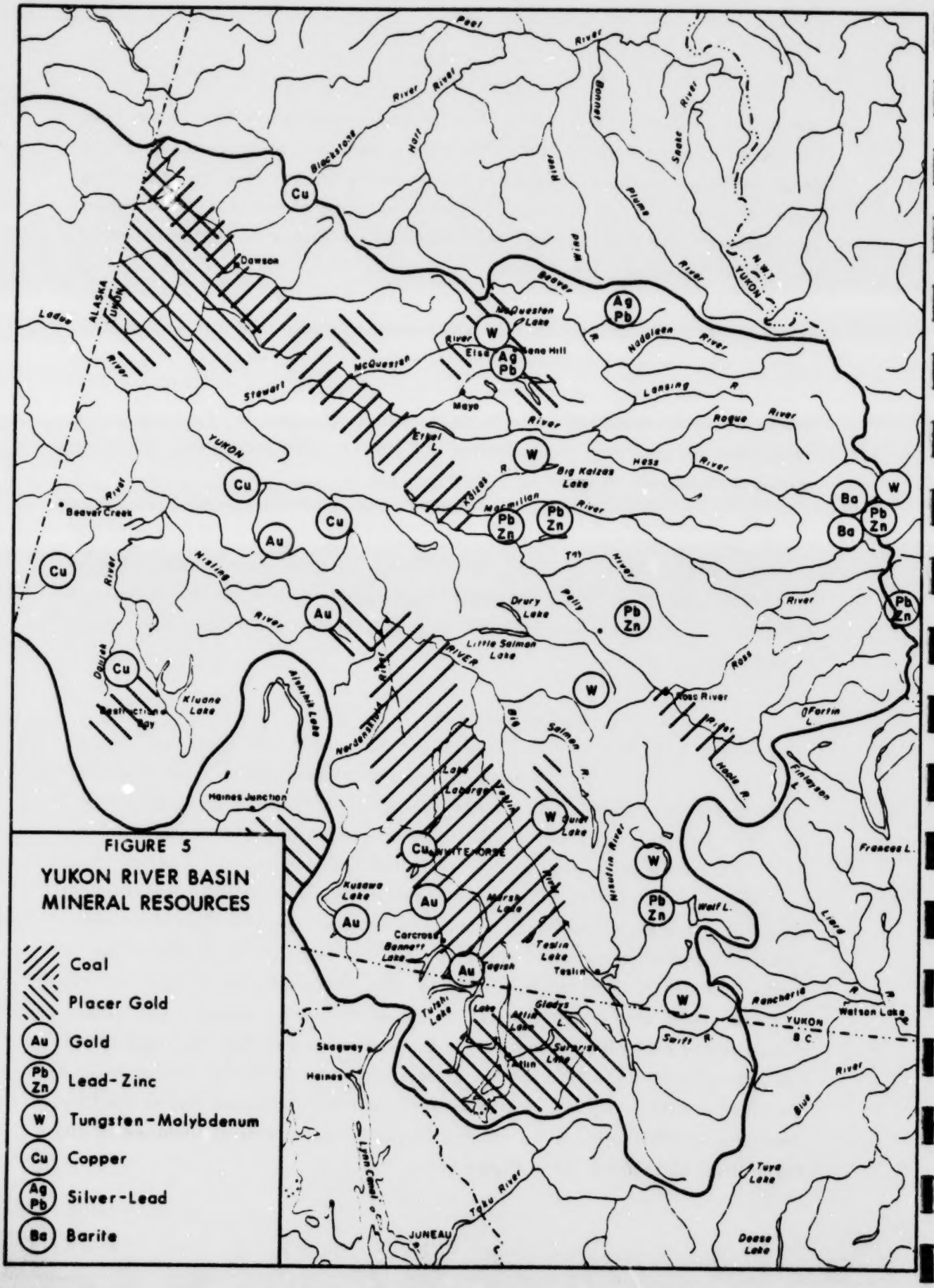
the system (Nicholls, 1981). Data from nearby areas, which have since been determined to be uncharacteristic of the system, were used to derive the necessary design criteria. Because of above average precipitation during the monitoring period long term annual inflows to the system were overestimated. A recent reassessment has shown the long term inflows to the system to be 82 percent of the original projection (Steen, 1984).

Existing developments may require hydrometeorological data for operational purposes. Applications of this type are reservoir inflow forecasts and control structure operations, water supply estimates and streamflow forecasts.

All proposed major developments and existing operations were evaluated with respect to hydrometeorological data requirements and specific recommendations were made to increase the adequacy of the existing networks. Potential developments include hydroelectric, mining, linear corridors and recreation. Major industrial and hydroelectric developments are interrelated and frequently collocated. An intermediate scale mining operation generally requires a minimum ten megawatts of power. Available power sources must therefore be assessed prior to development. If hydroelectric power is unavailable from a nearby source and cannot be economically developed, the proposed mining development may not be economically viable.

1.421 Mineral Resources

Mining activities in the Yukon River basin have undergone considerable changes since 1965. Prior to that year the major interest was in precious metals (gold, silver) since transportation costs were small in terms of the selling price. Since that time there has been a shift to base metals (lead, zinc, copper). During the 1970's several mines were in operation, including Anvil Mining Corporation in Faro which produces lead and zinc, Whitehorse Copper near Whitehorse, United Keno Hill in the Mayo area which produces silver, lead, zinc and cadmium, Cassiar Asbestos Corporation in Clinton Creek, and the Tantalus Butte coal mine in Carmacks which is operated by Anvil. In 1976 amendments to mining laws and improved prices accelerated exploration and development. Activity was further encouraged by exploration successes. In the eastern part of the basin exploration was concentrated in the Faro and Mayo areas and in the Selwyn Mountains, notably Macmillan and Howards Pass. In the western portion of the basin exploration took place around Whitehorse, Minto and the Dawson Range. Mineral resources of the Yukon River basin are noted in Figure 5.


Peel River
Bonnet Plume River
Snake River
Blackstone River
Hart River
Wind River
Dawson
ALASKA
YUKON
Lodge River
Stewart River
McQuesten
Beaver
McQuesten Lake
Elsa
Keno Hill
Mayo
Haddelgen River
Lansing R
Rogue River
Hess River
Ethel L
Big Kalzas Lake
Kalzas R
Macmillan River
Pelly River
Drury Lake
Little Salmon Lake
RIVER
Ross River
Beaver Creek
Nisling River
Klaane Lake
Alsek R
Haines Junction
Kusawa Lake
Aishihik Lake
Lake Laberge
Yukon
WHITEHORSE
Quiet Lake
Big Salmon R
Hootalinqua R
Finlayson L
Frances L
Hyland River
Wolf L
Carcross
Bennett Lake
Tagish
Teslin Lake
Teslin
Ranchería
Watson Lake
YUKON
B.C.
Swift R
Skagway
Haines
Atlin Lake
Atlin
Gladys L
Surprise Lake
Taku River
Tuya Lake
Blue River
JUNEAU
Dease Lake
Cu
Au
Pb Zn
W
Ag Pb
Ba
FIGURE 5
YUKON RIVER BASIN
MINERAL RESOURCES
Coal
Placer Gold
Gold
Lead-Zinc
Tungsten-Molybdenum
Copper
Silver-Lead
Barite

The Cassiar Asbestos mine in Clinton Creek closed in 1978 with the depletion of the ore body, and the Whitehorse Copper mine ceased production in 1983 for the same reason, though it may be taken over in the future and the tailings reworked. United Keno Hill reduced their operations during 1982 due to falling metal prices, and are currently operating on a limited basis. Cyprus Anvil is presently maintaining a waste stripping program only. Likewise, exploration activities during 1983 were greatly reduced and were again directed towards precious metals. It is anticipated, however, that production and exploration will accelerate again with rising prices. The most promising potential developmental areas have been identified (K. Grapes, 1984; DIAND, 1983) as being the MacTung, Tom, Jason, Tea, Howards Pass and Venus properties. Production by at least some of these properties may commence in the late 1980's if markets are favourable. The three primary areas of concern are Macmillan Pass, and Howards Pass in the Selwyn Mountains and the Venus area near Carcross.

The main placer areas are Dawson, Mayo, and Livingston Creek in the Big Salmon River basin.

1.422 Hydroelectric Resources

The Yukon River basin (including Aishihik hydroelectric plant which is part of the Whitehorse system) currently has an installed power generating capacity of approximately 115 MW. This includes the recently installed fourth generating unit at the Whitehorse Rapids plant. Of this total approximately 35 MW are produced by diesel generation. The existing power generating units in the Yukon River basin are listed in Table 7. In addition, a water use licence has recently been issued to Yukon Hydro Limited for construction of an additional hydroelectric generating facility on McIntyre Creek. Energy Exploration Limited of Vancouver has also recently applied for a water use licence to revitalize an existing hydroelectric plant in the Klondike River area utilizing diversions of both the North Klondike River and the main channel. It is assumed that the future will experience a steady hydroelectric load growth with the occasional large mining load required. With an abundant supply of water the Yukon River basin subsequently has a large number of potential sites where hydroelectric power can be developed economically. The potential sites have been identified, and to some extent socio-economic and environmental feasibility studies have been carried out, the most recent being Sigma et al (1975), Monenco (1977), Monenco (1980), Shawinigan Stanley (1982), Monenco (1983a), and Monenco (1983b).

TABLE 7 EXISTING POWER GENERATION IN THE YUKON RIVER BASIN

	GENERATING UNITS	TOTAL CAPACITY (MW)	
Hydroelectric			
Whitehorse Rapids	1 x 20 1 x 8.25 2 x 5.87	40	
Aishihik	2 x 15.5	31	
Mayo	1 x 2.24 1 x 2.83	5.1	
McIntyre Creek		1.65	
			77.75
Diesel			
Whitehorse Rapids		18.2	
Whitehorse Rapids (temporary)		7.5	
Faro		5.15	
Dawson		1.5	
Yukon Electric (misc)		5	
			37.35
			115.1

Sigma provides an updated inventory of all potential sites in the Yukon Territory and adjacent areas of the Northwest Territories with the capacity of 30 MW or more. This assessment was comprehensive in that it included all previous studies. Approximately 100 potential sites have been identified and twenty-three power projects were studied in greater detail. With further economic and locational analyses these were classified into three groups according to priority. Those projects within the Yukon River basin are listed in Table 8 and their locations are noted in Figure 6. For the purpose of this study primary projects only are considered.

Further analyses encompassed several alternate load projections in an attempt to define potential power requirements. A certain degree of uncertainty is associated with studies of this type since a single industrial user may have a demand of 20 MW or more. For this reason a range of system loads was projected, and three demand scenarios were evaluated. These are 75, 150 and 250 MW respectively. With each scenario the proposed schemes were ranked. Inspection of the various 75 and 150 MW scenarios identifies the Five Finger, Pelly (Hoole), Pelly (Granite) and Teslin as having relatively high priorities.

For the purpose of this review the 250 MW scenario is not considered since the probability of a required load increase of that magnitude within the next ten years is considered low. Generally for design purposes a ten year data base will provide usable information, and therefore this is a reasonable lead time.

Shawinigan Stanley (1982) discusses the engineering and cost aspects of the proposed False Canyon development on the Frances River. Though this project is outside the Yukon River basin it has been identified as an attractive scheme to provide additional energy to Faro and other nearby load centers. This development would provide 58 MW utilizing 44.6 meters of head and a resevoir which would include Frances Lake.

A preliminary engineering study carried out by Monenco (1983a) identified the Slate Rapids site on the Pelly River as an economical source of power for Faro and other nearby load centers. This scheme would provide 41.6 MW utilizing storage proposed earlier as the Upper Pelly storage to provide reservoir storage for the Hoole Canyon development.

Monenco (1977) carried out a study to assess the options available to NCPC to meet the increasing power demands in the Whitehorse system prior to the construction of a major hydroelectric development. This study was to supplement the earlier Sigma study by identifying potential projects in the 10 to 30MW range

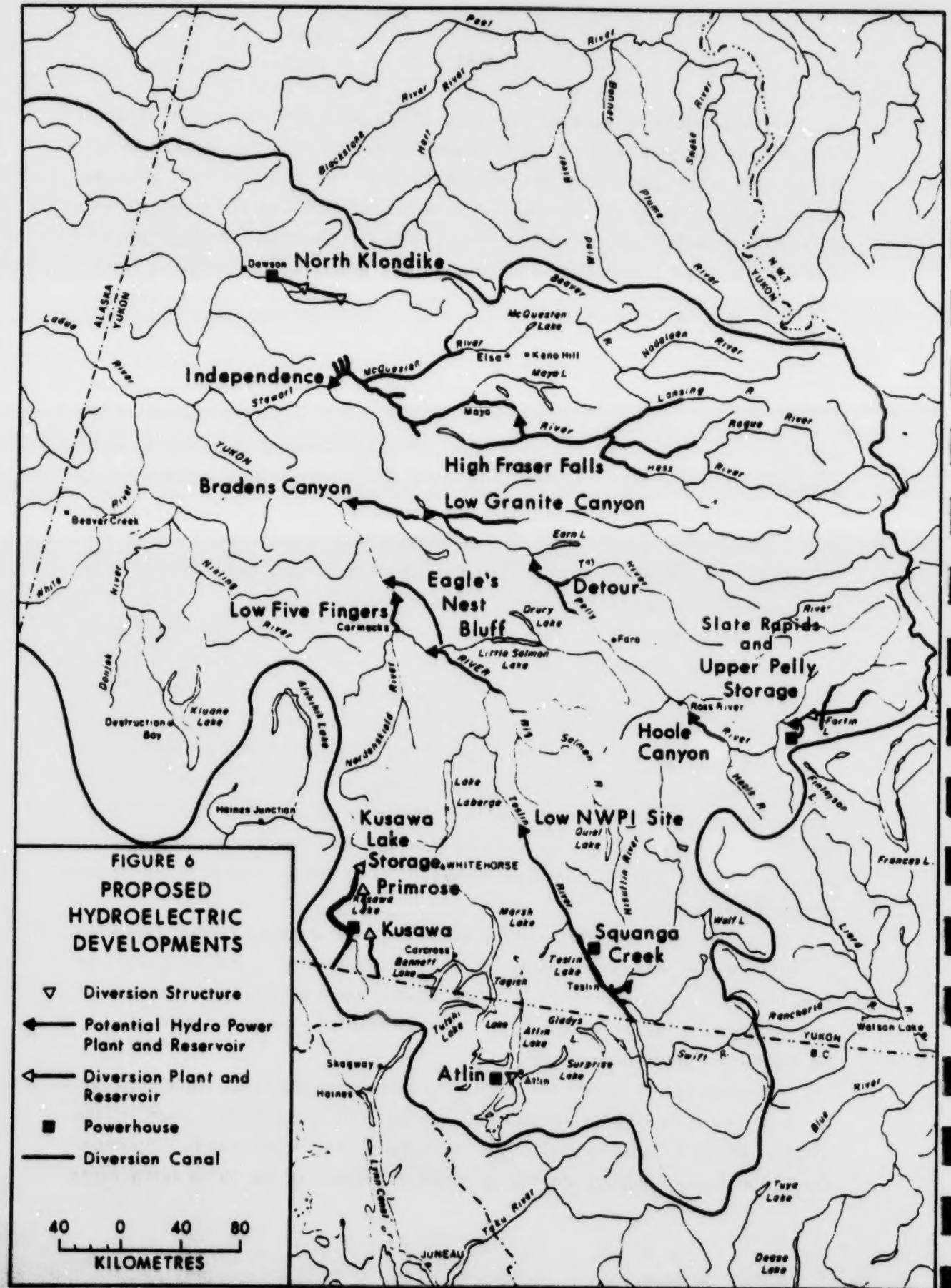

North Klondike
Dawson
Independence
Bradens Canyon
High Fraser Falls
Low Granite Canyon
Eagle's Nest Bluff
Low Five Fingers
Detour
Slate Rapids and Upper Pelly Storage
Hoole Canyon
Low NWPI Site
Kusawa Lake Storage
Primrose
Kusawa
Squanga Creek
Atlin
WHITEHORSE
Haines Junction
Beaver Creek
Destruction Bay
Carmacks
Faro
Ross River
Watson Lake
Skagway
Haines
JUNEAU
ALASKA
YUKON
N.W.T.
BC
FIGURE 6
PROPOSED HYDROELECTRIC DEVELOPMENTS
Diversion Structure
Potential Hydro Power Plant and Reservoir
Diversion Plant and Reservoir
Powerhouse
Diversion Canal
40 0 40 80
KILOMETRES

TABLE 8 PROPOSED HYDROELECTRIC DEVELOPMENTS

Primary Projects	
	Primrose/Kusawa
	Low NWPI
	Hoole Canyon
	Low Granite Canyon
	High Granite Canyon
	Low Fraser Falls
	High Fraser Falls
	Low Five Fingers
	High Five Fingers
	Eagles Nest Bluff
	Atlin Storage
	Squanga Creek
	North Klondike
	Slate Rapids
Secondary Projects	
	Bradens Canyon (with Low Granite Canyon)
	Bradens Canyon (with High Granite Canyon)
	Independence (with Low Fraser Falls)
	Independence (with High Fraser Falls)
	Ross Canyon
	Detour Canyon (without Pelly Lakes Storage)
	Detour Canyon (with Pelly Lakes Storage)

to accommodate relatively low load growth. The alternatives were limited to relatively small or intermediate sized schemes in the order of 20 MW or less and revolved about optimizing existing plants through diversions to increase available water supplies or increasing generating capacities. These included extensions to the Whitehorse Rapids plant, the Aishihik system, a small new development on Squanga Creek, and a storage facility on Atlin Lake. It is stressed by Monenco (1977) that most investigations reported are either at the prefeasibility or inventory level.

For analyses purposes annual load growths of 5, 7.5 and 10 percent and the addition of a block load of 20 to 50 MW were compared. Of the various alternate scheme combinations, Atlin storage in conjunction with the recently established Whitehorse expansion was the most attractive. This proposal would negate the need for the Aishihik diversions.

The proposed storage facility on Atlin Lake, with a range of approximately 2.3 meters of controlled storage, would increase the firm flow into Marsh Lake and subsequently provide an additional 5 MW of firm capacity at the Whitehorse Rapids plant.

The proposed Squanga Creek power development near Johnsons Crossing would generate 2 to 4 MW utilizing a 60 meter head and would be tied into the Whitehorse system using a proposed transmission line to Teslin. An additional one meter of lake storage could be developed with the construction of a control weir at the outlet of Squanga Lake.

A potential hydroelectric site exists on the Atlin River at a location between Atlin and Tagish Lakes where approximately 12 meters of head could be utilized. A dam at the lower end of the reach would provide the basis for a 10 MW plant.

In response to a strong opposition to a potential Yukon mainstem hydro development at Five Finger Rapids because of historic and tourism interests and flooding at Carmacks, Monenco (1980) undertook to locate an alternative economic site with acceptable historic, social and environmental consequences. The program concentrated on the middle reaches of the Yukon because of favourable flow characteristics, location of load centers, and potential mining development. Eagles Nest Bluff, near Carmacks, was found to be the most promising site, and now replaces the Five Finger Rapids proposal as the most feasible mid-Yukon power project. The three phases require a series of diversion and storage schemes. Its location is noted in Figure 6.

Monenco (1983b) carried out a review of all available reports on hydroelectric investigations in Yukon Territory and the Yukon River basin which were carried out over the last 25 years. These were summarized and an updated inventory was prepared. Proposed sites were given importance and study adequacy ratings using factors which included power benefits, timing and location criteria and socio-environmental concerns, and, assessments of the various necessary site inventory data. Comments regarding the suitability of each site were made, though ranking or priorizing was carried out. Recommendations were made for updating studies and satisfying deficiencies.

1.423 Linear Facilities

No new major highway corridors are proposed for the forseeable future, though work is continuously being carried out to upgrade the existing ones. Indirectly there is some road work associated with proposed mining and hydroelectric developments, the most significant being Howards Pass.

Potential pipeline corridors within the basin for the most part parallel the alignment of the existing highway networks. As an exception, the Alaska Highway Natural Gas Pipeline is proposed to deviate from the highway alignment in the Whitehorse area where it is routed through the Ibex Valley.

1.424 Recreation

No large potential recreation areas which would require hydrometeorlogical data for design information are planned. There have been discussions in the past, however, on designating certain streams with "heritage river" status. This occurrence may result in withdrawing the designated streams from future developmental concerns, therefore eliminating site specific data requirements. Design information may be required for the proposed road into St. Elias Park.

1.5 Summary of User Survey

The majority of stations comprising the various data collection networks within the Yukon River basin were initially established to meet site specific requirements. Within the last decade the importance of long term historical information for design criteria reinforced the need for baseline data. Information from the various data collection networks is used for many specific purposes by various government and private agencies. With accelerating development and population

growth the demand for additional information is continuously increasing, resulting in rising capital and operating costs. For this reason it is desirable to optimize the data collection networks with respect to both data gaps and redundant stations.

Since the data user groups and requirements are varied and are continuously changing, it is necessary to determine what the specific present and future needs may be. This was accomplished through a user survey using a standard questionnaire supplemented by telephone interviews and personal meetings with certain key primary users. Specifically, it was desirable to know the type and extent of data use, specific applications, and the users comments regarding the adequacy of the networks.

The questionnaire was adapted from one used by Acres (1977) which was modified to meet specific study needs. A sample questionnaire is included in the Appendix. The questionnaire results were compiled and interpreted by Reid Crowther and Partners Limited, and these are summarized below. Comments by respondents regarding specific aspects of the data collection networks are mentioned in the appropriate sections.

Questionnaires were sent to agencies and individuals making up the hydrometric and snow survey publication mailing lists of the Yukon region of the Department of Indian Affairs and Northern Development . It was thought that these lists would encompass users of the Water Survey of Canada hydrometric and Atmospheric Environment Service climatic data as well. Of 139 questionnaires sent out, 54 were returned, though three of these had been misaddressed and returned unopened, and three were returned by libraries which did not comment on the data network. The final response was 35 percent. The questionnnaire was broken down into three sections for interpretive purposes. These consist of sections on the utilization of data networks, specific data uses, and miscellaneous questions on use and network adequacy.

The first section provides information on the utilization of each component network by the respective users. This information is summarized in Table 9. The table indicates that information from all data collection networks except the DIAND hydrometric network is used extensively by the respondents. Only 47 percent of the sample used the DIAND hydrometric information. Each of the component networks has a small proportion of users which rely on it almost exclusively.

TABLE 9 USERS OF COMPONENT NETWORKS BY QUESTIONNAIRE RESPONDENTS

PERCENTAGE OF USE FRACTILE	WSC HYDROMETRIC	AES CLIMATIC	BC/DIAND SNOW SURVEY	DIAND HYDROMETRIC
0	23%	9%	12%	53%
1 - 10	13%	20%	37%	27%
11 - 20	2%	15%	5%	4%
21 - 30	11%	22%	9%	6%
31 - 40	6%	9%	5%	2%
41 - 50	13%	13%	9%	4%
51 - 60	9%	-	2%	-
61 - 70	6%	-	2%	-
71 - 80	4%	2%	-	2%
81 - 90	6%	7%	-	-
91 - 100	6%	4%	2%	-
	100%	100%	100%	100%
Percentage of sample using data type	77%	91%	88%	47%

The second section provides information on specific uses of the data by the respondents. The survey indicates that of the three broad application categories 55 percent of the uses are for investigative purposes, 28 percent for design purposes, and 17 percent for operational purposes. This information is summarized in Table 10. There does not appear to be a single dominant application, though the data is used equally as extensively for several applications. The data use which has the least applicability is that associated with irrigation and navigation. These statistics do not reflect the relative importance of the project type or the specific component network, but the interest of the various user groups.

In addition to those uses initially included in this survey, other uses became evident. These are environmental impact assessments, public information, fire forecasting and management, sediment loading, and fisheries assessment.

One particularly interesting response came from the United States Soil Conservation Service in Anchorage under the navigation category who reported using hydrometric data for forecasting Bering Strait sea ice breakup, an important concern for shipping purposes.

The third section provides information on specific concerns and needs of the particular user groups. It is here that site specific deficiencies can be made known. These are summarized below by user group.

Engineering Firms

Specific uses include flood frequency analysis, hydrologic modelling, low flow studies, runoff forecasting, hydrograph analysis, flood routing and stream crossing design. Within this category 50 percent of the respondents considered the hydrometric network to be adequate for large basins, and 50 percent considered the network to be inadequate. Information for small basins was generally considered to be inadequate. Specific comments were made with reference to the length of the data base and station density. The majority of respondents suggested a record length in excess of 25 years to be appropriate. The lack of information on sediment loading was also mentioned. Generally, hydrometric and snow course network density was considered to be inadequate. The comment was made that all information should be readily available in a computer format as well as published in the traditional manner. No redundant stations were identified.

TABLE 10 APPLICATIONS OF HYDROMETEOROLOGICAL DATA

PROJECT TYPE	NUMBER OF USERS IN SAMPLE ADDRESSING PROJECT TYPE	PERCENT OF SAMPLE N = 41	NUMBER OF APPLICATIONS OF DATA IN EACH PROJECT			
			INVESTIGATION	DESIGN	OPERATION	TOTAL APPLICATIONS
1. Planning and Resource Evaluation	22	54%	18	7	3	28
1. Stream Crossing	22	54%	19	13	4	36
2. Flood Forecasting	21	51%	16	10	8	34
2. Water Quality Assessment	21	51%	15	8	6	29
3. Flood Control (dike, diversion)	20	49%	17	9	5	31
4. Hydroelectric	19	46%	19	7	5	31
5. Water Use (industrial)	17	41%	12	9	4	25
6. Flood Control (storage)	14	34%	13	8	4	25
17. Instream Demands	12	29%	10	5	2	17
17. Stormwater Drainage	12	27%	10	7	3	20
8. Water Use (residential & municipal)	11	27%	9	7	4	20
9. Wildlife Habitat Assessment	10	24%	8	1	1	10
0. Water Use (irrigation)	6	15%	7	2	1	10
1. Navigation	3	7%	3	0	1	4
			183	94	55	333
% of Total Applications by Project Phase			55%	28%	17%	

Resource Management Agencies

Specific applications include fire management studies, moisture regime analyses, climate and public information forecasts, flood assessments and habitat assessments. No comment was made on the adequacy of hydrological data, but it was mentioned that the climate station network is too sparse. Specific comments suggested needs for a more dense climate and snow course network and more information for small basins. It was suggested that annual summaries of information would be useful. Other comments suggested that river break-up and freeze-up dates should be published. In addition, the need for winter low flow measurements on small streams was stressed for assessing fish wintering capabilities. No redundant stations were identified by this user group.

Federal Technical Agencies

Specific applications include flood forecasting, snowpack characterization, fisheries studies, hydrograph analysis, hydrologic modelling, climatological studies, stream icing studies, and environmental impact assessments. General comments suggested that information from small drainage basins was inadequate. The comment was made that these will become statistically significant with time if the DIAND program continues. It was also suggested that a minimum ten year record length was necessary. A special mention was made of the need for daily weather information. A need for climatological information from higher elevations was stressed. The White River area was identified as a region lacking in hydrologic information. More data is needed for this area to characterize the unique hydrologic regime. The comment was made that user input should be sought in determining the potential site of data collection stations. No redundant stations were identified by this user group.

British Columbia Provincial Government Agencies

Specific applications included flood and low flow frequency analyses and snowpack characterization. The overall density of the snow course network was thought to be inadequate, especially at higher elevations. The upper Atlin and Teslin basins were cited as specific areas lacking information. Record lengths of 20 to 25 years were suggested as being appropriate. No redundant stations were identified by this user group.

Hydroelectric Companies

Specific applications include flood frequency analyses, reservoir routing, and water licence reporting. Generally, the snow course network was found to be inadequate, as well as hydrometric information from small basins. A record length of 50 years was cited as being necessary. Specific comments were made with respect to data availability to the user. It was mentioned that the Water Survey of Canada Hydrometric data arrives too late to be of any use. Annual updates were suggested as being appropriate for the DIAND hydrometric network, and ideally certain AES climatic information, which is needed for reservoir operation, could be made available monthly. The present arrangement of distributing the snow course information was satisfactory. Specific deficiencies are again cited to exist for small basins. In connection with reservoir regulation, weekly monitoring of large lakes is desirable. Tagish Lake was given as an example of where this information would be useful. In addition, it was suggested that a remote data platform at the Water Survey of Canada Marsh Lake station would be of great utility. No redundant stations within the Yukon River basin were identified; however, it was mentioned that the Sekulman Lake station in the Aishihik system duplicates the information provided by the stream flow station at the outlet of Sekulman Lake.

United States Government Agencies (Alaska)

Specific applications include the already mentioned Bering Sea ice breakup forecast, as well as Yukon River volume flow forecasting at Eagle, Alaska. It is mentioned that the snow course network density is inadequate, especially at higher elevations. In addition, longer record lengths are required. It is suggested that recording snow course stations using snow pillows be located at key locations to register maximum snowpack values.

In summary, the information provided by the major user groups indicates that generally the density of hydrometric networks is inadequate for small drainage basins; climatic and snow course information is inadequate, especially at higher elevations; record lengths are generally inadequate for many uses; the frequency of recording information and reporting it is inadequate, and more winter low flow information is needed.

2.0 HYDROMETRIC NETWORKS

Watershed discharge represents the integrated result of meteorological inputs and the physical characteristics of the basin. It is the only component of the hydrological cycle which allows accurate measurement of spatial average while the measurement of other components represent only point samples with considerable spatial variation.

Long term streamflow information is generally obtained from water elevation measurements which have been related to discharge. The discharge rating curve for a particular stream represents a unique relationship between water level and discharge at a given location and ideally will remain constant over time. Once the relationship has been established it is necessary only to obtain a measurement of water level which is taken with a reference to a fixed elevation. This can be done manually using a staff gauge or other technique requiring an observer, or a recording gauge. Several types of stations are in use; the choice of the particular type depends on the data use. This will determine the required accuracy, resolution, measurement interval and cost consideration.

The most basic station consists of a crest stage gauge, which provides a single stage measurement between visits. This type of station usually consists of a vertically mounted pipe which allows the maximum attained water level to be recorded using a material which adheres to the inside of the pipe. This gauge provides an inexpensive means of obtaining peak flow measurements.

A continuous recording gauge provides an actual hydrograph of streamflow by recording water level elevation values during the period of operation. The simplest continuous recording gauge consists of a clock driven roll chart mounted on a stilling well containing a float assembly which records stage variation on the chart. A stage-discharge rating curve is required to translate these to discharge. The rating curve is obtained by periodic velocity and cross sectional area measurements also related to stage. A more sophisticated recorder utilizes hydrostatic pressure variation to indicate a change in water level. Nitrogen gas is forced through a small diameter plastic tubing, the outlet of which is placed below water level. The hydrostatic pressure in the tube at any elevation is a result of the depth of water above the tube outlet. Pressure is transmitted through the tube to the recorder using a monometer.

The required hydrometric station type, operating period and network density are determined by data use. There are many uses of hydrometric data, including

applications relating to water supply, hydroelectric power generation, and flood control. Specific uses include, from a planning and design and operating point of view, basin and reservoir water availability assessments, reservoir operation, flow forecasting of peak and low flows, pollution control applications, and legal licencing applications. Various hydrometric data collection agencies classify individual stations into several categories, but these may generally be categorized as baseline or site specific.

2.01 Baseline Hydometric Network

Baseline information is required for long term planning and design purposes. This network should provide representative information which can be transferred to ungauged areas or to areas where only a small amount of streamflow is available. With the increasing use and application of statistical concepts and techniques it is essential that this network consist of stations with sufficiently long records to provide the basis for statistical definition. A minimum of ten years is needed (Janowicz, 1983); however, a record in the order of 25 years is desirable (Benson and Carter, 1973). In a study carried out by Ingeldow (1969) 50 years was recommended. The optimum record length for a particular station varies as a function of the variability of streamflow characteristics such as mean, low or peak flows. This can be approximated with consideration of the standard error of estimate (Benson and Carter, 1973). The standard error of estimate represents time sampling errors which generally decrease with progressively greater record lengths.

Baseline stations should be located in watersheds that have undergone no significant artificial alterations and are expected to remain so in the future. They should be well distributed areally to account for varying hydrologic characteristics and should represent a range of drainage areas. Since this network is intended to provide information representative of the entire annual hydrograph continuous recording stations are required as opposed to a selected time interval.

Several agencies have proposed guidelines defining the optimum separation of hydrometric stations. According to Hydrocon (1981) the Water Survey of Canada guidelines recommend one station per 3,000 and 1,500 square kilometers respectively for flat and mountainous areas. This criteria roughly corresponds to earlier guidelines developed by Water Survey of Canada for the designation of major stream gauging stations (Water Survey of Canada, 1975). This report summarizes previous studies dealing with hydrometric network design with the objective of

providing the basis for the design of a major stream inventory network for British Columbia and Yukon Territory. World Meteorological Organization criteria were used to define a major stream as a stream which has at least one tributary with drainage areas of approximately 1,000 square kilometers (400 square miles) and 2,500 square kilometers (1,000 square miles) for mountain and flat regions respectively. For the purpose of that study the Yukon River basin was assumed to be mountainous. In addition, it was recommended that downstream stations be established at points where inflows increase by fifty percent. It was recommended that these stations be operated for an indefinite period. Selection of individual stations to make up this network was based on the inspection of topographic maps. Though the proposed network was thought to provide only minimum coverage, it would represent the framework for an optimum network design. Shawinigan (1970) suggests additional major stream stations for several western and northern Canada rivers, including the Yukon River, at points where inflows increase by 40 percent. The World Meteorological Organization (1980) suggested an optimum and minimum acceptable density of one station per 5,000 and 20,000 square kilometers respectively. For comparison purposes Hydrocon (1981) cites ratios of one station per 6,800 and 26,000 square kilometers for the Yukon River basin within Canada and Alaska respectively. The use of the above guidelines is not recommended since they tend to oversimplify network planning and they should be used for comparison purposes only. They may be more applicable in prairie regions or areas which exhibit a more homogeneous hydrologic response. In practice, guage density is a function of population density and economic development since this represents a need for water use (Langbein, 1965). Ingledow (1969) recommends concentrations of stations in selected areas as opposed to saturation coverage of large areas.

Several recent hydrometric network studies have incorporated in their conclusions recommendations for the application of techniques to transfer information from gauged to ungauged basins (Shawinigan, 1970, Solomon, 1972, Ingledow, 1969), and others suggest that data transfer must be an integral component of a network (Benson and Carter, 1973). Moss et al (1982) refers to a hydrologic information network as collectively consisting of a group of stations and a mechanism for transferring the information to ungauged areas.

2.02 Site Specific Hydrometric Network

Site specific stations provide information that is required for current use and for planning and design purposes for proposed developments. The information provided by this network can be related to specific needs; therefore, it may have little usefulness for transfer purposes. No general guidelines or criteria are available to optimize the location and distribution of site specific stations. Depending upon the utility of the data the location, type and period of operation may be specified by the user. This network may consist of various types of stations which are tailored to meet the specific requirements of the user. If annual peak flows are the only information required, this data ideally can be obtained very cost effectively utilizing crest stage gauges with minimal visits. Similarly, if low flow summer only information is required a station operated during the period of interest only will be the most cost effective. If information with greater accuracy is required then the station can be designed accordingly.

A potential station location may be predetermined or well defined as is the case with uses pertaining to reservoir operation or where legal surveillance requirements are being met. However, where this information is required for broader scale applications such as water availability assessments for proposed major hydroelectrical developments, locational criteria similar to those used for baseline considerations may be applicable here.

The demand for site specific stations normally increases with increasing development and the network changes frequently in response to changing needs. The characteristics of the stations making up the network cannot be planned in the long run with any degree of certainty. The operation of the individual stations must be justified by a current need for the information. Once the need has been fulfilled the station should be discontinued. In certain areas stations comprising the baseline network may also provide information for site specific needs. Historically the majority of hydrometric stations in Canada were initially established for site specific purposes. This is the case with the networks operated by both Water Survey of Canada and the Department of Indian Affairs and Northern Development.

2.03 Hydrometic Network Operated by Water Survey of Canada

The hydrometric network in Yukon Territory was formally implemented in 1944 with discharge measurements of the Yukon River at Whitehorse by the Water Resources Branch of the Dominion and Power Bureau. Hydrometric stations were established over the next few years at existing stage guage locations along the major transportation corridors. The early 1950's brought on the second phase of development in reponse to the proposed hydroelectric projects, the Yukon-Taiya and the Yukon-Taku developments (Kreuder, 1980). These projects involved the diversions of upper Yukon basin waters to Pacific drainages, thus the southwest portion of the Territory was instrumented. The late 1950's saw the establishment of several Yukon main stream and large tributary stations to assess the hydropower potential of the Yukon River. Similarly, the Liard River was instrumented in 1960, and the Peel and Porcupine Rivers in the early 1960's in response to proposed hydroelectric developments. With accelerated resource development in the Territory during this period, private companies requested flow information for design considerations. This resulted in the establishment of several site specific hydrometric stations. The development of the hydrometric network within the Yukon River basin is presented in Table 11. Included are stations within the nearby Alsek River drainage.

DIAND was formed in 1965 as a result of a departmental reorganization and was given the responsibility of overseeing resource development in the northern Territories. It was not until the early 1970's that DIAND took an active role in the WSC hydrometric stream gauging network. A proposal for the orderly development of the hydrometric network in the Territory was formulated in 1971 by WSC (Water Survey of Canada, 1971). This consisted of 54 regional stations and eight major stream stations based on a grid coverage. This document initiated active discussions between DIAND and WSC with respect to hydrometric development in Yukon Territory. An informal agreement was signed in 1975 which, among other features, provided for planning the reconnaissance and construction of stations several years in the future. WSC released its proposal for a major stream inventory network to provide a source of potential stations to draw upon (Water Survey of Canada, 1975). In 1978 a five-year proposal for network development was agreed upon by the administrators of the Yukon Water Quantity agreement. This was based on the consideration of the present data network and anticipated future needs.

TABLE 11 HISTORICAL DEVELOPMENT OF THE HYDROMETRIC NETWORK OPERATED BY WATER SURVEY OF CANADA WITHIN THE YUKON RIVER BASIN

1944 - 1948	
09AB001	Yukon River at Whitehorse
09AE002	Teslin Lake at Teslin
09AE001	Teslin River near Teslin
09EB001	Yukon River at Dawson
09DC001	Mayo River near Mayo (discontinued in 1951)A
09AA004	Bennett Lake at Carcross
09DC002	Stewart River at Mayo
09AC001	Takhini River near Whitehorse
1949 - 1952	
08AA001	Aishihik River near Whitehorse
09AB004	Marsh Lake near Whitehorse
09AC004	Takhini River at outlet of Kusawa Lake
09AC005	Kusawa Lake near Whitehorse
09AA003	Dezadeash River at Haines Junction
09CA002	Kluane River at outlet of Kluane Lake
09CA001	Kluane Lake near Burwash Landing
09AH001	Yukon River near Carmacks
09AB009	Yukon River above Frank Creek
09AA006	Atlin River near Atlin
09AA	Atlin Lake near Atlin
09AA	Pine Creek near Atlin (discontinued in 1970)
09AA003	Lindeman Lake near Bennett
1953 - 1954	
09AF001	Teslin River near Whitehorse (discontinued in 1974)
09AA007	Lubbock River near Atlin
09BC001	Pelly River at Pelly Crossing
09AA010	Lindeman Creek near Bennett
09AE004	Gladys River at outlet of Gladys Lake

TABLE 11 HISTORICAL DEVELOPMENT OF THE HYDROMETRIC NETWORK OPERATED BY WATER SURVEY OF CANADA WITHIN THE YUKON RIVER BASIN (Continued)

1955 - 1956	
09AB008	M'Clintock River near Whitehorse
09AA012	Wheaton River near Carcross
09AA009	Watson River near Carcross (discontinued in 1974)
09AA011	Tagish Creek near Carcross (discontinued in 1971)
09AG001	Big Salmon River near Carmacks
09BC002	Pelly River at Ross River (stage only from 1976; disc. 1981)
09AA015	Wann River near Atlin
09AA014	Fantail River at outlet of Fantail Creek
09AA016	Fantail Lake near Atlin
09AA013	Tutshi River at outlet of Tutshi Lake
09AE003	Swift River near Swift River
1957 - 1958	
09CD001	Yukon River above White River
09EB002	Yukon River at Stewart (discontinued in 1974)
09DD003	Stewart River at the mouth
09BA001	Ross River at Ross River
09DD002	Stewart River at Stewart Crossing (discontinued in 1973)
1959 - 1966	
08AA004	Kathleen River near Haines Junction (discontinued in 1974)
10EC001	Clinton Creek above Wolverine Creek (discontinued 1966)
09EA003	Klondike River above Bonanza Creek
09BC003	Rose Creek below Faro Creek (discontinued in 1969)
1972 - 1974	
08AA005	Aishihik Lake near Whitehorse
09BC004	Pelly River below Vangorda Creek

TABLE 11 HISTORICAL DEVELOPMENT OF THE HYDROMETRIC NETWORK OPERATED BY WATER SURVEY OF CANADA WITHIN THE YUKON RIVER BASIN (Continued)

1974 - 1975	
08AB001	Alsek River above Bates River
09AH003	Big Creek near the mouth
09CB001	White River at km 1881.6 Alaska Highway
09BB001	South MacMillan River at km 401 Canol Road
09EA004	North Klondike River near the mouth
1975 - 1976	
09CB001	White River at km 1881.6 Alaska Highway
1976 - 1977	
09DA001	Hess River above Emerald Creek
1978 - 1979	
09AD001	Nisutlin River above Wolf Creek
09DD004	McQuestin River near the mouth
1979 - 1980	
09CA003	Donjek River below Kluane River
09DC005	Mayo Lake near the outlet
09DC004	Wareham Lake at headgate
09DC003	Stewart River above Fraser Falls
1980 - 1981	
09CA004	Duke River near the mouth
09AB010	Lake Laberge near Whitehorse
08AA010	Aishihik River below Aishihik Lake
09AA009	Giltana Creek near the mouth
08AA008	Sekulman River at outlet of Sekulman Lake
08AA007	Sekulman Lake near Whitehorse
09DC006	Stewart River near Mayo

TABLE 11 HISTORICAL DEVELOPMENT OF THE HYDROMETRIC NETWORK OPERATED BY WATER SURVEY OF CANADA WITHIN THE YUKON RIVER BASIN (Continued)

1981 - 1982	
09EC002	Fortymile River near the mouth
09EB003	Indian River above the mouth
09AG002	Quiet Lake at km 98 South Canol Highway
1982 - 1983	
09GA003	South Big Salmon River near Livingstone Creek
09AH004	Nordenskiold River below Rowlinson Creek
09EA005	Little South Klondike River below Ross Creek
1983 - 1984	
08AC001	Takhanne River
09BB002	Macmillan River near the mouth

The proposed network plan initiated a systematic hydrometric development which as its goal sought to provide coverage for the entire Territory in such a fashion as to facilitate the estimation of hydrologic characteristics for unguaged basins with some degree of confidence using regional techinques. The original network plan was revised several times in response to continually changing objectives and financial limitations. The basic framework remains unchanged, which is to satisfy the needs of three district information classes: regional, major stream and site specific.

The regional category was originally based on a uniform grid or transect coverage of the Territory, but evolved slightly to provide comprehensive regional coverage for all homogeneous physiographic units. This generally includes basins with drainage areas less than 1,300 square kilometers.

The major stream network includes those sites which would provide information for major river basin planning programs. These are generally intermediate and large basins with area in excess of 1,300 square kilometers.

With the introduction of methodical basin planning in the last decade, the hydrometric network has approximately doubled in size. During this period the network has expanded to include representative basins in every region of the Territory. A few exceptions are evident, primarily for small drainage areas. In addition, accelerating resource development resulted in the rapid increase in the number of site specific stations. The existing hydrometric network within the Yukon River basin consists of 46 stations. In addition, the nearby Alsek River drainage contains nine stations. The historical network is listed in Table 12 and their locations are noted in Figure 7.

TABLE 12 YUKON RIVER BASIN - HISTORICAL HYDROMETRIC NETWORK OPERATED BY WATER SURVEY OF CANADA

STATION NUMBER	STATION NAME	DRAINAGE AREA (km^2)	GAUGE LOCATION (Lat./Long.)	DISCHARGE RECORDS (*-STAGE ONLY #-MISC.MEAS.) TYPE OF GAUGE, OPERATION	REMARKS
08AA010	Aishihik River below Aishihik Lake	2 960	61 11 04 136 59 24	80- RC	REG 74
09AA009	Giltana Creek near the mouth	194	61 11 50 136 58 42	80- RS	NAT
08AA008	Sekulman River at outlet of Sekulman Lake	1 250	61 33 50 137 31 57	80- RS*	NAT
08AA007	Sekulman Lake near Whitehorse		61 32 25 137 33 00	80- RC*	NAT
08AB001	Alsek River above Bates River	16 200	60 07 09 137 58 27	74-79 RC	NAT
08AA003	Dezadeash River at Haines Junction	8 500	60 44 54 137 30 19	52 M# 53-70 MC 71-79 RC	REG 74
08AA005	Aishihik Lake near Whitehorse		61 11 53 136 59 53	72-79*RC	REG 74
08AA001	Aishihik River near Whitehorse	4 300	60 51 40 137 03 40	50-58 MC 59-60 MS 61-68MC 69-79 RC	REG 74
08AA004	Kathleen River near Haines Junction	642	60 35 35 137 13 45	59-64 MC	NAT
09AB010	Lake Laberge near Whitehorse		61 05 25 135 11 57	80- RC*	REG 25
09AA006	Atlin River near Atlin	6 810	59 35 57 133 48 48	50-79*MC	NAT
09AA001	Atlin Lake at Atlin		59 34 30 133 42 31	50-79*MC	NAT
09AA008	Pine Creek near Atlin	697	59 33 40 133 39 56	52 M# 55-61 MC 62-64 MS 65-70 MC	NAT

.../continued

M - Manual Gauge
R - Recording Gauge
P - Power Plant

C - Continuous Operation
S - Seasonal Operation

NAT - Natural Flow
REG - Regulated since 19...
(Year shown if known)

TABLE 12 YUKON RIVER BASIN - HISTORICAL HYDROMETRIC NETWORK OPERATED BY WATER SURVEY OF CANADA (Continued)

STATION NUMBER	STATION NAME	DRAINAGE AREA (km^2)	GAUGE LOCATION (Lat./Long.)	DISCHARGE RECORDS (*-STAGE ONLY #-MISC.MEAS.) TYPE OF GAUGE, OPERATION			REMARKS
09AA015	Wann River near Atlin	269	59 25 55 134 12 20	56 #	57-63 RS	64-79 RC	NAT
09AA014	Fantail River at outlet of Fantail Lake	717	59 35 40 134 23 26	56-60 RS	61-79 RC		NAT
09AA016	Fantail Lake near Atlin		59 35 39 134 24 03	57-79*RS			NAT
09AA013	Tutshi River at outlet of Tutshi Lake	829	59 56 48 134 19 29	56-58 RS	59-61 RC	62-79 RC	NAT
09AA010	Lindeman Creek near Bennett	240	59 50 16 135 00 50	54-66 RS 73-79 RC	67-71 RC	72 MC	NAT
09AA003	Lindeman Lake near Bennett		59 50 00 135 00 46	50-66*MC 73-79*RC	67-71*RC	72*MC	NAT
09AC005	Kusawa Lake near Whitehorse		60 35 16 136 08 38	52-69*RS	70-79*RC		NAT
09AB002	Yukon River above Control Dam near Whitehorse		60 34 37 134 40 42	41 46*MC	50-57*MC		REG 25
09AB003	Yukon River below Control Dam near Whitehorse		60 34 45 134 41 15	41-45 MC	50-57MC	59-60 MC	REG 25
09AB001	Yukon River at Whitehorse	19 400	60 42 50 135 02 35	02-27*MS 70-72 RC	28-42*MC 73-79 PC	43-69 MC	REG 26
09AB004	Marsh Lake near Whitehorse		60 31 50 134 21 55	50-51*MC 66-79*RC	52*MS	53-65*MC	REG 25
09AB008	M'Clintock River near Whitehorse	1 700	60 36 45 134 27 27	55-79 RC			NAT
09AA007	Lubbock River near Atlin	1 770	60 04 52 133 51 30	52 #	54 R#	55-57 RS 68-79 RC	NAT
09AA004	Bennett Lake at Carcross		60 04 52 134 42 27	52 #	54 R#	55-57 RS	NAT
09AA012	Wheaton River near Carmacks	875	60 08 05 134 53 45	55-65 RS	66-79 RC		NAT

TABLE 12 YUKON RIVER BASIN - HISTORICAL HYDROMETRIC NETWORK OPERATED BY WATER SURVEY OF CANADA (Continued)

STATION NUMBER	STATION NAME	DRAINAGE AREA (km^2)	GAUGE LOCATION (Lat./Long.)	DISCHARGE RECORDS (*-STAGE ONLY #-MISC.MEAS.) TYPE OF GAUGE, OPERATION	REMARKS
09AA009	Watson River near Carcross	1 150	60 13 00 134 43 50	55-61 MC 62-65 M# 66-73 RC 74 #	NAT
09AA011	Tagish Creek near Carcross	76.9	60 17 32 134 18 00	55-57 MS 58 MS 59 MS 60-62 MC 63-64 # 65-71 RC	NAT
09AC004	Takhini River at outlet of Kusawa Lake	4 070	60 36 37 136 07 26	52 RS 53-54 RC 55-56 RS 57 M# 58 RS 59-62 RC 63 RS 64-79 RC	NAT
09AC001	Takhini River near Whitehorse	6 990	60 51 08 135 44 21	48-63 MC 64-79 RC	REG 48
09AD002	Sydney Creek at km 46.2, South Canol Highway	372	60 47 05 133 03 15	81- RS	NAT
09AE003	Swift River near Swift River	3 320	59 55 50 131 46 04	56-57 MS 58 MC 59-60 MS 61-79 RC	NAT
09AE004	Gladys River at outlet of Gladys Lake	1 910	59 54 20 132 54 50	54-55 # 56-60 RS 61-79 RC	NAT
09AE002	Teslin Lake at Teslin		60 09 52 132 42 12	44-48*MC 49*MS 51-79*MC	NAT
09AE001	Teslin River near Teslin	30 300	60 29 04 133 18 07	44-46 MS 48-76 MC 77-79 RC	NAT
09AF001	Teslin River near Whitehorse	36 500	61 29 21 134 46 35	51 M# 53-54 M# 55-71 RC 74 C	NAT
09AD001	Nisutlin River above Wolf River		60 20 35 132 32 41	79 RC	NAT
09AG002	Quiet Lake at km 46.2, South Canol Highway		61 08 35 133 04 50	81- RC*	NAT
09GA003	South Big Salmon near Livingstone Creek		61 23 10 134 22 15	82- RS	NAT
09AH004	Nordenskiold River below Rowlinson Creek	6 370	62 03 00 136 16 45	82- RS	NAT
09AG001	Big Salmon River near Carmacks	6 760	61 52 22 134 50 00	51 # 53-58 RS 59-61 M# 62-63 RS 64-79 RC	NAT

TABLE 12 YUKON RIVER BASIN - HISTORICAL HYDROMETRIC NETWORK OPERATED BY WATER SURVEY OF CANADA (Continued)

STATION NUMBER	STATION NAME	DRAINAGE AREA (km^2)	GAUGE LOCATION (Lat./Long.)	DISCHARGE RECORDS (*-STAGE ONLY #-MISC.MEAS.) TYPE OF GAUGE, OPERATION	REMARKS
09AH003	Big Creek near the mouth	1 750	62 34 07 137 00 58	74-79 RC	NAT
09AB009	Yukon River above Frank Creek	30 800	61 26 04 135 11 18	51 # 53-55 RS 56-79 RC	REG 25
09AH001	Yukon River at Carmacks	81 100	62 05 45 136 16 18	51-59 MC 60-79 RC	REG 25
09CD001	Yukon River above White River	150 000	63 08 59 139 33 10	56-64 MC 65-79 RC	REG 25
09EB002	Yukon River at Stewart River	251 000	63 18 42 139 25 43	56-65 MC	NAT
09EB001	Yukon River at Dawson	264 000	64 04 12 139 25 30	44*MC 45-52 MC 54-55 MS 56-73 MC 74-79 RC	REG 25
09BC002	Pelly River at Ross River	18 400	61 59 12 132 26 54	51 # 54-59 MS 60-74 RS 75*RS 76-79*MS	NAT
09BC004	Pelly River below Vangorda Creek	22 100	62 13 20 133 22 40	70-71 M# 72-79 RC	NAT
09BC001	Pelly River at Pelly Crossing	49 000	62 49 47 136 34 50	51-59 MC 60-79 RC	NAT
09BA001	Ross River at Ross River	7 250	61 59 40 132 22 40	58-59 # 60-63 MC 64-79 RC	NAT
09BC003	Ross Creek below Faro Creek	208	62 20 30 133 24 30	66-67 MS 68-69 MC	REG
09BB001	South MacMillan River at km 401, Canol Road	997	62 55 20 130 32 30	74-79 RC	NAT
09CA004	Duke River near the mouth	631	61 21 37 139 09 23	80- RS	NAT
09CB001	White River at km 1881.6, Alaska Highway	6 240	61 58 57 140 33 16	74-79 RC	NAT
09CA003	Donjek River below Kluane River		62 04 56 139 51 35	79 RC	NAT

TABLE 12 YUKON RIVER BASIN - HISTORICAL HYDROMETRIC NETWORK OPERATED BY WATER SURVEY OF CANADA (Continued)

STATION NUMBER	STATION NAME	DRAINAGE AREA (km^2)	GAUGE LOCATION (Lat./Long.)	DISCHARGE RECORDS (*-STAGE ONLY #-MISC.MEAS.) TYPE OF GAUGE, OPERATION	REMARKS
09CA002	Kluane River at outlet of Kluane Lake	4 950	61 25 37 139 02 56	52-60 MC 61-79 RC	NAT
09CA001	Kluane Lake near Burwash Landing		61 03 18 138 30 12	53-60*MC 61-79*RC	NAT
09DC005	Mayo Lake near the outlet		63 46 24 135 23 17	79- RC*	REG 52
09DC004	Wareham Lake at Headgate		63 39 24 135 55 02	79- RC*	REG 52
09DC003	Stewart River above Fraser Falls	30 600	63 29 17 135 08 06	79- RS	NAT
09DC006	Stewart River near Mayo	31 600	63 35 26 135 53 46	80- RS*	NAT
09DC001	Mayo River near Mayo	2 260	63 42 07 135 51 43	45-47 MS 49-51 MS 53#	REG
09DD004	McQuesten River near the mouth	2 870	63 36 40 137 16 10	79- RC	NAT
09DC003	Stewart River above Fraser Falls		63 29 17 135 08 06	79 RC	NAT
09DC002	Stewart River at Mayo	31 600	63 35 26 135 53 48	47-48 # 49-71 MC 72-79 RC	NAT
09DD002	Stewart River at Stewart Crossing	35 000	63 22 56 136 40 59	58 M# 60 M# 6-73 RC	NAT
09DD003	Stewart River at the mouth	51 000	63 16 55 139 14 56	51 # 56-62 # 63-79 RC	NAT
09DA001	Hess River above Emerald Creek	4 840	63 19 50 131 30 00	76-79 RC	NAT
09EC002	Forty Mile River near mouth	16 600	64 23 50 140 36 40	81- RS	NAT
09EB003	Indian River above the mouth	2 220	63 46 16 139 37 45	81- RS	NAT

TABLE 12 YUKON RIVER BASIN - HISTORICAL HYDROMETRIC NETWORK OPERATED BY WATER SURVEY OF CANADA (Continued)

STATION NUMBER	STATION NAME	DRAINAGE AREA (km^2)	GAUGE LOCATION (Lat./Long.)	DISCHARGE RECORDS (*-STAGE ONLY #-MISC.MEAS.) TYPE OF GAUGE, OPERATION			REMARKS
09EA005	Little South Klondike River below Ross Creek		63 59 45 137 34 20	83- RS			NAT
09EC001	Clinton Creek above Wolverine Creek		64 26 54 140 42 24	64-65 MS			NAT
09EA003	Klondike River above Bonanza Creek	7 800	64 02 34 139 24 28	65-73 MC 77-79 RC	74-75 RC	76 MC	NAT
09EA004	North Klondike River near the mouth	1 100	64 01 16 138 34 58	74-79 RC			NAT

M - Manual Gauge
R - Recording Gauge
P - Power Plant

C - Continuous Operation
S - Seasonal Operation

NAT - Natural Flow
REG - Regulated since 19...
(Year shown if known)

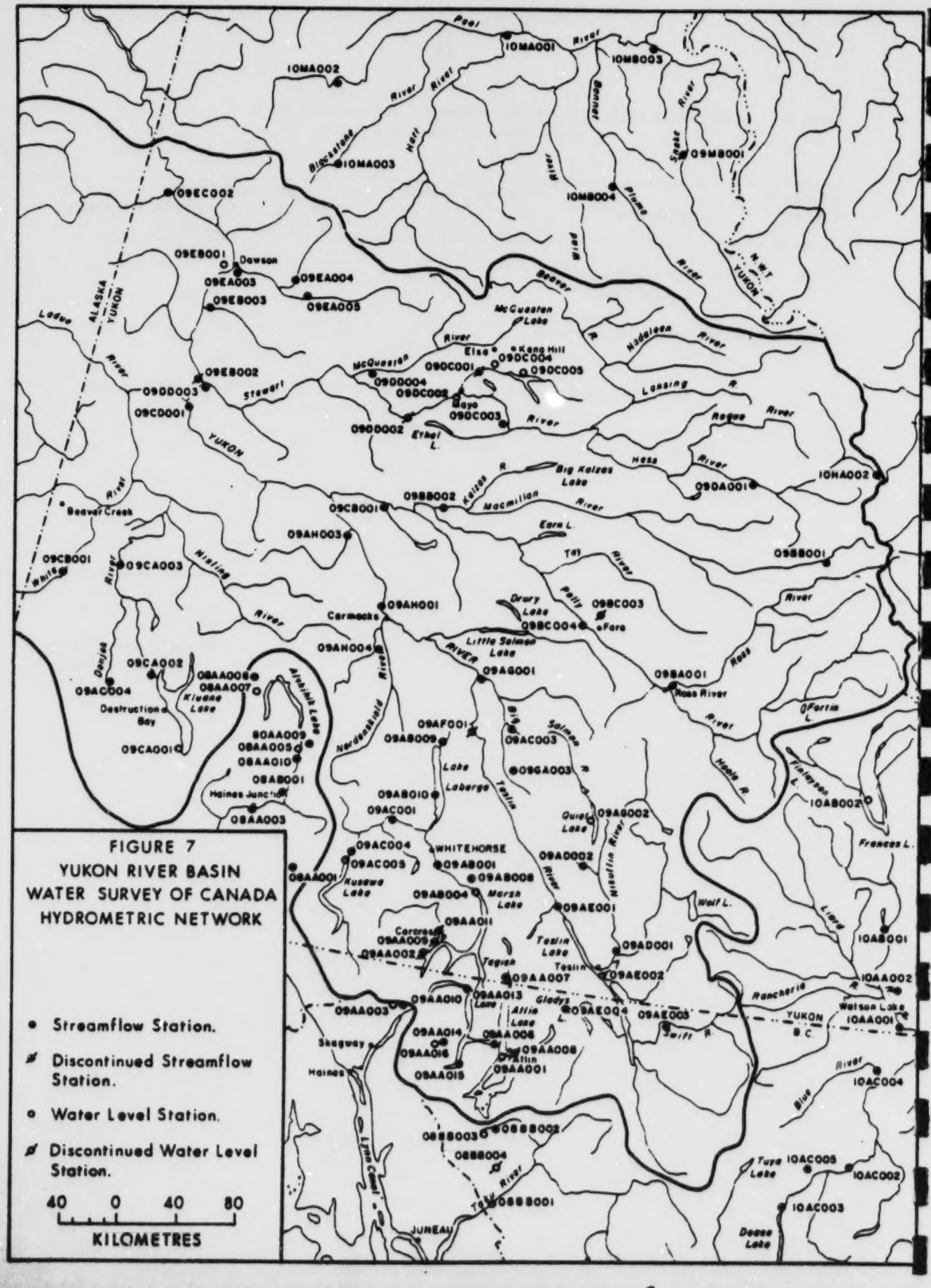


FIGURE 7
YUKON RIVER BASIN
WATER SURVEY OF CANADA
HYDROMETRIC NETWORK
• Streamflow Station.
Discontinued Streamflow Station.
o Water Level Station.
Discontinued Water Level Station.
40 0 40 80
KILOMETRES
Peel River
Bonnet Plume River
Snake River
Wind River
Beaver River
Hess River
Rogue River
Nadaleen River
Lansing R.
Big Kalzas Lake
Kalzas R.
Macmillan River
Earn L.
Tay Rivers
Pelly River
Ross River
Hoole R.
Finlayson L.
Frances L.
Wolf L.
Liard River
Rancheria R.
Watson Lake
Blue River
Tuya Lake
Dease Lake
Stewart River
Ladue River
Beaver Creek
White River
Donjek River
Nisling River
Kluane Lake
Destruction Bay
Aishihik Lake
Nordenskiold River
Haines Junction
Kusawa Lake
Marsh Lake
Laberge
Teslin
Teslin Lake
Tagish
Gladys Lake
Atlin Lake
Carcross
Skagway
Haines
Lynn Canal
Taku River
JUNEAU
Swift R.
YUKON
B.C.
ALASKA
YUKON
N.W.T.
Dawson
WHITEHORSE
Carmacks
Little Salmon Lake
Drury Lake
Fora
Quiet Lake
Big Salmon R.
Fort L.
McQuesten Lake
Elsa
Keno Hill
Mayo
Ethel L.
09EC002
09EB001
09EA003
09EA004
09EB003
09EA005
09EB002
09DD003
09CD001
09DD004
09DC001
09DC004
09DC005
09DC002
09DC003
09DD002
09CB001
09AH003
09CA003
09AH001
09AH004
09CA002
09AC004
09AA006
09AA007
09CA001
09AA009
09AA005
09AA010
09AB001
09AA003
09AB009
09AB010
09AC001
09AC003
09GA003
09AF001
09AG001
09AA001
09AC005
09AB008
09AB004
09AA011
09AA002
09AA007
09AA010
09AA013
09AA003
09AA014
09AA016
09AA015
09AA006
09AA008
09AA001
09AB002
09AD002
09AE001
09AD001
09AE002
09AE004
09AE003
09BA001
09BB001
09BC003
09BC004
09BA002
09BB002
09BB003
09BB004
09BB001
10MA001
10MA002
10MA003
10MB003
09MB001
10MB004
10HA002
09DA001
10AB002
10AB001
10AA002
10AA001
10AC004
10AC005
10AC002
10AC003

2.04 Hydrometric Network Operated by the Northern Affairs Program

The hydrometric network operated by DIAND was initiated in 1974 on a project oriented basis with the objective of providing one or two years of flow information primarily for culvert design and fisheries concerns. The establishment of the network was prompted by the realization that very little hydrometric information was available for small drainage basins with areas in the order of 500 square kilometers and smaller. This was noted by WSC in their 1971 network proposal. With increasing development the importance of information for these basins became apparent. Because of the inverse relationship between unit discharge and drainage area hydraulic structures associated with small basins are susceptible to relatively great peak flow events. Because of this the practice of transforming information to small ungauged areas using larger watersheds as a base is questionable.

The original areas of interest were the North Canol, Nahanni Range, and the Dempster Highways. The desired information was obtained using inexpensive crest stage guages which provided a single peak stage value per service interval. These were converted to discharge using a stage-discharge rating curve. The network was operated during the open water season only, with no attempt at winter readings. The data was first published by DIAND in 1975.

Development in the Territory accelerated with the proposed Foothills and Shakwak projects. As a result of these proposals additional requests for data were received. This resulted in the Alaska, Haines and South Canol Highways being added to the network in 1976 and 1977. In addition, requests for data from private companies resulted in the establishment of stations in the Faro and Clinton Creek areas. This period saw the installation of nine recorder sites, thus providing continuous records instead of the single point value. In 1978 several recorders were installed in the Dawson area to monitor placer operations. The Skagway Highway was also instrumented in response to the proposed oil pipeline.

In 1979, as a result of increasing work loads on DIAND Water Resources' staff, it was decided to let the network operation out on contract. This was not followed through, however, and the in house operation continued.

At the end of 1979 the Nahanni Range Highway was dropped from the network, as was the South Canol Highway in 1980. The stream crossings on these roads had been replaced, therefore operation of these segments were no longer cost effective. Flow information for small basins in these areas is available from

Water Survey of Canada, who established a hydrometric station on Sidney Creek on the South Canol Highway and King Creek on the Nahanni Range Highway.

In 1980, 58 stations were operated, with 21 of these being recorders. In 1981 these values increased to 63 and 22, and in 1982, 77 and 28 respectively. Of the 1982 network, 15 of the stations were requested by the Northern Roads and Airports Branch of the Northern Affairs Program. These were located on the North Canol Highway in anticipation of realigning the road in response to increasing development in the Macmillan Pass area.

As noted, the small stream network was originally established to provide short term, project-oriented information on flow characteristics of small streams. The network has expanded considerably, however, through several requests by private and other government agencies for data to meet development pressures. Presently, the network provides coverage for much of the highway system in the Territory with many of the stations having record lengths of up to nine years. The historical DIAND hydrometric network is listed in Table 13 and their locations noted in Figure 8.

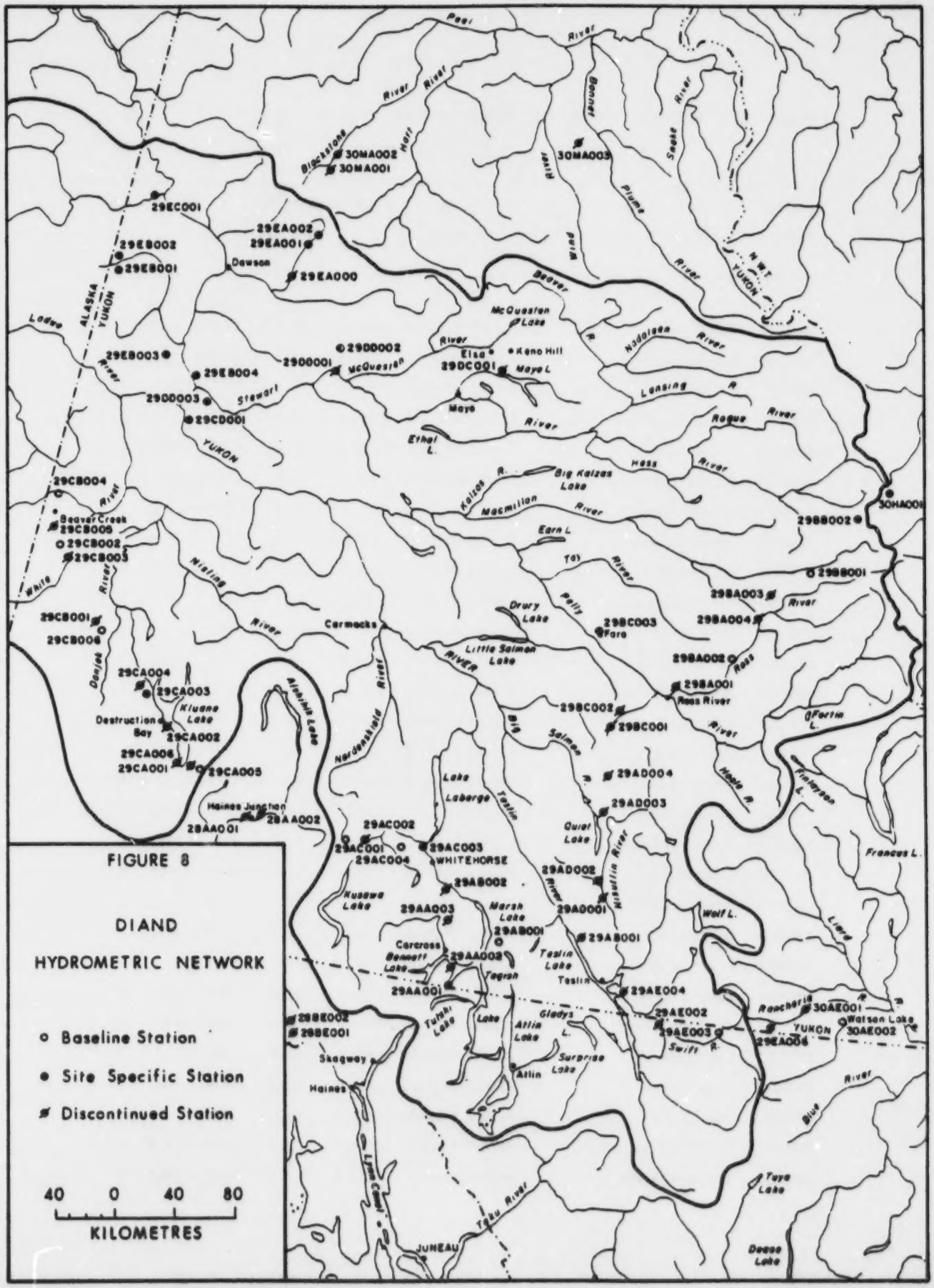


FIGURE 8
DIAND
HYDROMETRIC NETWORK
Baseline Station
Site Specific Station
Discontinued Station
40 0 40 80
KILOMETRES
Peel River
Bonnet River
Snake River
Bonnet Plume River
Hart River
Blackstone River
30MA002
30MA001
30MA003
29EC001
29EA002
29EA001
29EB002
29EB001
Dawson
29EA000
ALASKA
YUKON
Lodge River
29EB003
29EB004
2900002
2900001
McQuesten
2900003
Stewart
29CD001
YUKON
McQuesten Lake
Elsa
Keno Hill
29DC001
Maye L
Maye
Ethel L.
Beaver R.
Nadaleen River
Leasing R.
Rogue River
Hess River
Kaiser R.
Big Kaiser Lake
Macmillan River
Earn L.
Tay River
Pelly River
29CB004
Beaver Creek
29CB005
29CB002
29CB003
White River
Nisling River
29CB001
29CB006
Carmacks
Drury Lake
Little Salmon Lake
RIVER
29BC003
Faro
29BA003
29BA004
29BA002
29BA001
Ross River
29BC002
29BC001
Big Salmon River
Hoole R.
Finlayson L.
Frances L.
Dodson
29CA004
29CA003
Kluane Lake
Destruction Bay
29CA002
29CA006
29CA001
29CA005
Alsek R.
Aishihik Lake
Nordenskiold River
Haines Junction
28AA002
28AA001
29AC002
29AC001
29AC004
29AC003
WHITEHORSE
Lake Laberge
Teslin
29AD004
29AD003
Quiet Lake
Hotalinqua River
29AD002
29AD001
29AB002
Kusawa Lake
29AA003
Marsh Lake
29AB001
Wolf L.
Liard
Carcross
Bennett Lake
29AA002
Tagish
Teslin Lake
Teslin
29AA001
29AE004
29AE002
29AE003
Swift R.
Rancheria
30AE001
Watson Lake
30AE002
YUKON
29EA004
29BE002
29BE001
Tutshi Lake
Lake
Atlin Lake
Gladys L.
Atlin
Surprise Lake
Skagway
Haines
Lynn Canal
Taku River
JUNEAU
Blue River
Tuya Lake
Dease Lake

TABLE 13 HISTORICAL HYDROMETRIC NETWORK OPERATED BY DIAND

STATION NUMBER	STATION NAME	GENERAL LOCATION	KM	DRAINAGE AREA (km^2)	RECORD PERIOD	GAUGE TYPE
30AE002	Big Creek	Alaska Highway	1084.8	607.1	1978 -	R
30AE001	Spencer Creek	Alaska Highway	1118.6	112.3	1978 - 1982	C
29AE006	Freer Creek	Alaska Highway	--	45.8	1979 - 1982	R
29AE003	Partridge Creek	Alaska Highway	1184.9	59.7	1978 -	R
29AE002	Logjam Creek	Alaska Highway	1209.6	64.6	1978 - 1982	C
29AE004	Strawberry Creek	Alaska Highway	1266.2	67.8	1979 - 1982	C
29AE001	Deadman Creek	Alaska Highway	1323.1	147.5	1978 - 1982	C
29AB001	Judas Creek	Alaska Highway	1402.7	170.9	1979 -	R
29AB002	Wolf Creek	Alaska Highway	1458.6	196.8	1979 - 1982	C
29AC003	Unnamed Creek	Alaska Highway	1492.0	27.8	1979 -	R
29AC004	Ibex Creek	Alaska Highway	--	456.8	1979 -	R
29AC002	Stoney Creek	Alaska Highway	1538.1	44.7	1978 - 1982	C
29AC001	Mendenhall Creek	Alaska Highway	1557.9	774.2	1976 -	R
28AA002	Marshall Creek	Alaska Highway	1618.9	160.4	1978 - 1982	C
28AA001	Bear Creek	Alaska Highway	1645.9	71.5	1976 - 1982	C
29CA005	Christmas Creek	Alaska Highway	1687.8	59.6	1979 -	R
29CA001	Silver Creek	Alaska Highway	1696.0	48.1	1978 - 1979	C
29CA006	Congdon Creek	Alaska Highway	1724.8	59.3	1976 - 1982	C
29CA002	Unnamed Creek	Alaska Highway	1743.0	6.7	1978 - 1982	R
29CA003	Burwash Creek	Alaska Highway	1776.2	97.4	1978 - R	
29CA004	Quill Creek	Alaska Highway	1788.6	76.1	1979 - 1982	C
29CB006	Edith Creek	Alaska Highway	1844.2	297.1	1979 -	R
29CB001	Long's Creek	Alaska Highway	1859.5	104.6	1976 - 1982	R
29CB003	Sandpete Creek	Alaska Highway	1896.0	50.8	1978 - 1982	C
29CB002	Dry Creek #2	Alaska Highway	1905.0	152.8	1976 -	R
29CB005	Enger Creek	Alaska Highway	1924.0	65.2	1979 - 1982	C
29CB004	Snag Creek	Alaska Highway	1945.6	676.0	1978 -	R
28AC002	Gribble's Gulch	Haines Road	193.9	22.3	1975 - 1978	C
28AC003	Takhanne River	Haines Road	167.2	383.1	1975 - 1983	R

TABLE 13 HISTORICAL HYDROMETRIC NETWORK OPERATED BY DIAND (Continued)

STATION NUMBER	STATION NAME	GENERAL LOCATION	KM	DRAINAGE AREA (km^2)	RECORD PERIOD	GAUGE TYPE
28AC001	Stanley Creek	Haines Road	143.5	78.5	1977 - 1982	C
28BE001	Mule Creek	Haines Road	123.1	24.3	1976 - 1982	R
28BE002	Stonehouse Creek	Haines Road	101.8	12.4	1977 - 1982	C
29AD001	Murphy Creek	S. Canol Road	32.6	112.1	1977 - 1980	R
29AD002	Sidney Creek	S. Canol Road	46.2	365.7	1976 - 1980	C
29AD003	Rose River #1	S. Canol Road	104.9	939.1	1976 - 1980	C
29AD004	Rose River #4	S. Canol Road	146.4	287.2	1976 - 1980	C
29BC001	Groundhog Creek	S. Canol Road	161.9	65.0	1977 - 1980	C
29BC002	Bacon Creek	S. Canol Road	178.2	60.1	1977 - 1980	C
29BA001	Tenas Creek	N. Canol Road	238.6	159.3	1975 - 1978	R
29BA002	180 Mile Creek	N. Canol Road	259.8	97.9	1975 -	R
29BA004	Twin Creek #1	N. Canol Road	343.3	24.5	1978 - 1982	R
29BA003	Riddell Creek	N. Canol Road	354.1	65.8	1975 - 1982	C
29BB001	Boulder Creek	N. Canol Road	387.0	37.0	1977 -	R
29BB002	South MacMillan River #2	N. Canol Road	438.6	194.3	1975 -	R
29BB003	Sekie Creek #1	N. Canol Road	445.6	14.2	1981 - 1982	C
29BB004	S.MacMillan R. @ Pan Ocean	N. Canol Road	--	131.6	1981 - 1982	C
29BB005	MacIntosh Creek	N. Canol Road	448.3	1.3	1981 - 1982	C
29BB006	Sekie Creek #2	N. Canol Road	450.0	5.2	1981 - 1982	C
29BB007	Sekie Creek #2A	N. Canol Road	--	1.9	1981 - 1982	C
29BB008	South MacMillan River #3	N. Canol Road	452.2	73.6	1981 - 1982	R
29BB009	Sioux Creek	N. Canol Road	--	14.2	1981 - 1982	C
29BB010	Terrible Creek	N. Canol Road	--	13.6	1981 - 1982	C
29BB011	South MacMillan River #4	N. Canol Road	458.8	27.7	1981 - 1982	R
29BB012	South MacMillan River #5	N. Canol Road	460.6	14.2	1981 - 1982	C
29BB013	South MacMillan River #6	N. Canol Road	462.5	13.6	1981 - 1982	C
30HA001	Dale Creek	N. Canol Road	--	13.5	1977 -	R
29EA000	Benson Creek	Dempster Hwy.	29.6	100.5	1975 - 1976	C
29EA001	Wolf Creek	Dempster Hwy.	52.0	57.5	1975 - 1982	C
29EA002	Grizzly Creek	Dempster Hwy.	60.4	34.2	1975 - 1982	C

TABLE 13 HISTORICAL HYDROMETRIC NETWORK OPERATED BY DIAND (Continued)

STATION NUMBER	STATION NAME	GENERAL LOCATION	KM	DRAINAGE AREA (km^2)	RECORD PERIOD	GAUGE TYPE
30MA001	Blackstone River	Dempster Hwy.	120.1	616.9	1975 - 1982	C
30MA002	Unnamed Creek	Dempster Hwy.	132.5	238.7	1977 - 1982	C
30AD001	Jackpine Creek	Nahanni Range R	62.2	81.1	1975 - 1979	C
30AD002	Spruce Creek	Nahanni Range R	66.4	143.2	1975 - 1979	C
30AD003	Conglomerate Creek	Nahanni Range R	74.8	217.3	1975 - 1978	C
30AD004	South Moose Creek	Nahanni Range R	84.8	47.7	1975 - 1979	C
30AD005	Flood Creek	Nahanni Range R	100.3	60.6	1975 - 1979	R
29AA003	Bear Creek	Carcross-Skagway	--	18.5	1978 - 1980	C
29AA002	Big Thing Creek	Carcross-Skagway	--	23.9	1978 - 1980	R
29AA001	Pooly Creek	Carcross-Skagway	--	8.3	1978 - 1980	C
29DC001	Duncan Creek	Mayo Area	--	415.5	1979 - 1982	R
30MA003	Illtyde Creek	Mayo Area	--	665.8	1980 - 1981	R
29DD002	Clear Creek	Dawson Area	--	338.4	1979 -	R
29EA003	Hunker Creek	Dawson Area	--	200.3	1981 - 1982	R
29EB001	Sixty Mile Creek	Dawson Area	--	450.6	1977 -	R
29EB002	Big Gold Creek	Dawson Area	--	86.1	1979 -	R
29EC001	Clinton Creek	Dawson Area	--	130.1	1978 -	R
29EB003	Matson Creek	Dawson Area	--	224.5	1979 -	R
29CD001	Thistle Creek	Dawson Area	--	211.3	1980 -	R
29EB004	Henderson Creek	Dawson Area	--	341.9	1981 -	R
29DD003	Scroggie Creek	Dawson Area	--	755.5	1981 -	R
29BC003	Vangorda Creek	Faro Area	--	73.8	1977 -	R

Explanation of Guage Type: C - Crest Guage, peak flows only

R - Continuous Recording Guage

2.1 Hydrologic Regionalization

The objectives of the study were to evaluate the hydrometeorologic data networks within the Yukon River basin with the intent of identifying information gaps and redundant stations. Since the adequacy of the baseline network was to be assessed for its ability to define the streamflow characterization at any stream location within the basin, a regionalization approach was thought to be most appropriate. This would provide the basis for transferring information from gauged to ungauged basins using readily obtainable parameters. Specific transfer techniques are not discussed here. Ingledow (1969) suggested that a stream gauging network must be viewed as a sampling process which must be supplemented with a regional data transfer technique, but recommended that the network not be built around a particular method, thus permitting greater freedom for the development of new techniques.

2.11 Physical Hydrologic Regions

The regionalization procedure was based on the premise that regions subject to similar climatic and physiographic variation should likewise yield uniform hydrologic responses. Five major hydrologic zones were thought to make up the basin (Figure 9). This delineation was based on the simultaneous comparison of physiography and climate and consideration of mean annual runoff (Figures 10, 11, and 12). Brief descriptions of the physically derived hydrologic units follow.

The Western Mountains hydrologic region is comprised of the rugged St. Elias Mountains and Coast Mountains on the western boundary area of the Yukon River basin. The region is within the St. Elias-Coastal Mountain climatic area which is an area of heavy precipitation resulting in extensive snow and ice fields in the higher elevations (Wahl, 1983). Temperatures are less extreme than other parts of the basin due to the moderating effect of the Pacific air masses. Streamflow is characterized by peak flows occurring in the late summer, primarily in response to glacial inputs. Mean annual runoff based on stations with at least ten years of record ranges from 40 cm for the Takhini River at the outlet of Kusawa Lake to 131 cm for Lindeman Creek near Bennett Lake. Of the seven long term stations within this zone the mean runoff is 72 cm.

The Southern Interior zone drains the southern portion of the Yukon Plateau which consists of the Teslin and southern half of the Lewes plateaux. This region is bounded by the St. Elias and Coast Mountains on the west and the Pelly Mountains on the east. The northern boundary has a general east-west orientation at a point near Carmacks. The region, which is within the Upper Yukon-Stikine climatic zone, is relatively dry since it is within the rain shadow presented by the western mountain barriers. Temperatures are less extreme than northern and eastern areas due to moderating Pacific influences. The hydrologic regime is characterized by peak flows in June, primarily in response to snowmelt inputs, with low flows in March and April. Mean annual runoff ranges from 8 cm for the Lubbock River to 29 cm for the Teslin River near Whitehorse which has considerable lake regulation and also drains portions of the higher precipitation Southern Mountains region. The mean runoff of the seven long term stations is 19 cm.

The Northern Interior hydrologic zone is comprised of the remaining northern and eastern plateau areas of the Yukon River basin. These include the northern half of the Lewes Plateau and the Klondike Plateau west of the Tintina Trench, and the Stewart, Macmillan and Pelly plateaux east of the Tintina Trench. Consisting primarily of disected uplands, this region represents the largest hydrologic region within the basin. It is bounded by the St. Elias Mountains on the west and the Ogilivie and Selwyn Mountains on the north and east respectively. This zone is within the Central Yukon climatic region with a considerable range in temperature extremes and generally greater precipitation than the rainshadow areas to the south. The hydrologic response is chararacterized by primarily early summer peak runoff events due to snowmelt. Smaller basins are also susceptible to peak flows due to rainfall inputs. Unfortunately, hydrometric information is available for four stations only, three of which are Pelly River stations. Mean annual runoff for these stations ranges from 29 to 32 cm.

The Southern Mountains hydrologic zone consists of the Pelly and Cassiar Mountains. In the lower elevations the Nisutlin Plateau is between the two systems. This region is generally within a unique climatic zone referred to by Wahl (1983) as the Pelly-Cassiar climatic zone. These mountains act as a secondary orographic barrier for Pacific air masses. Since elevations are higher than the surrounding plateau areas it receives greater precipitation amounts and has cooler summers and less severe winters. The streamflow regime is characterized by snowmelt peaks in

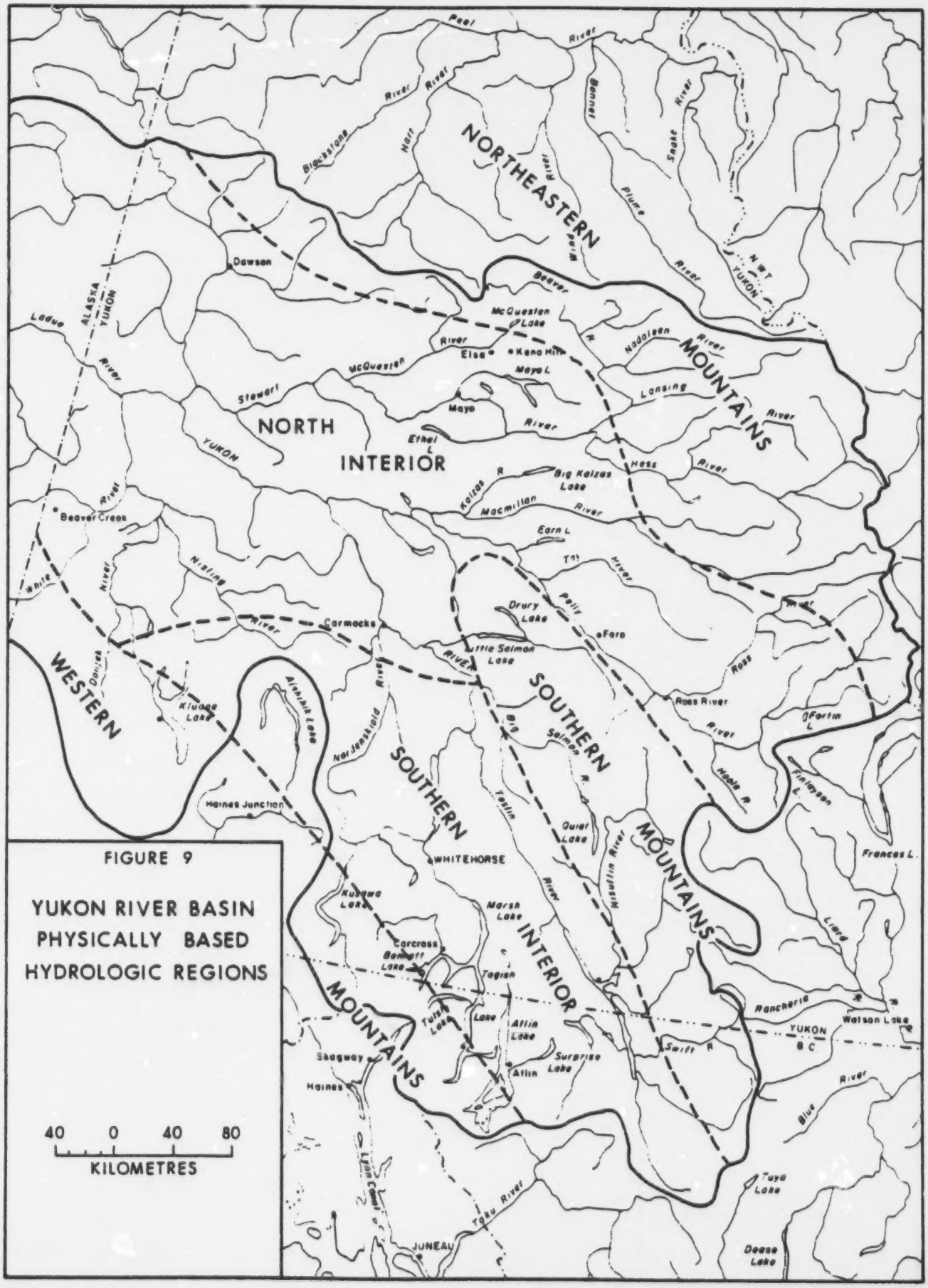


FIGURE 9

YUKON RIVER BASIN
PHYSICALLY BASED
HYDROLOGIC REGIONS

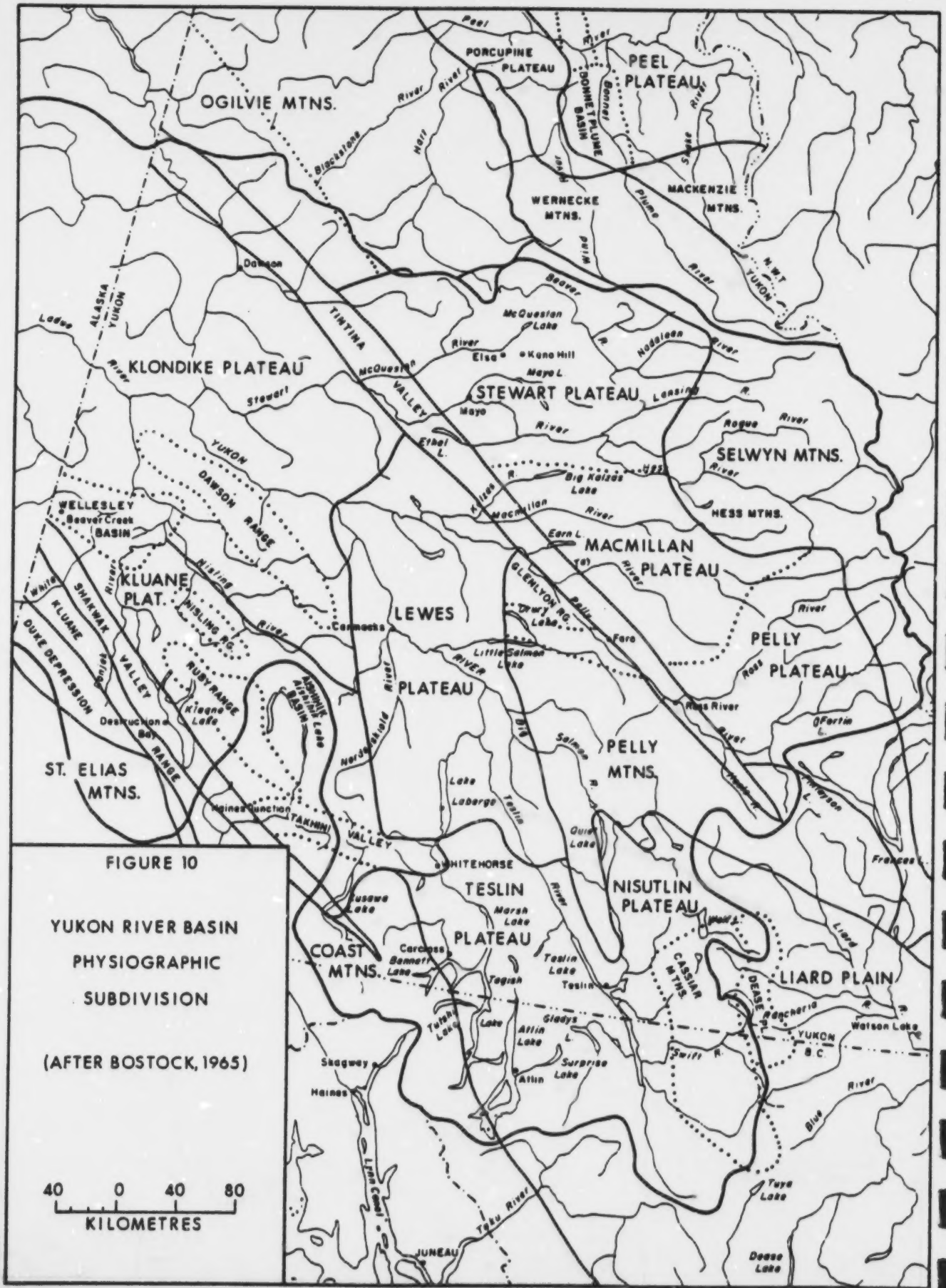
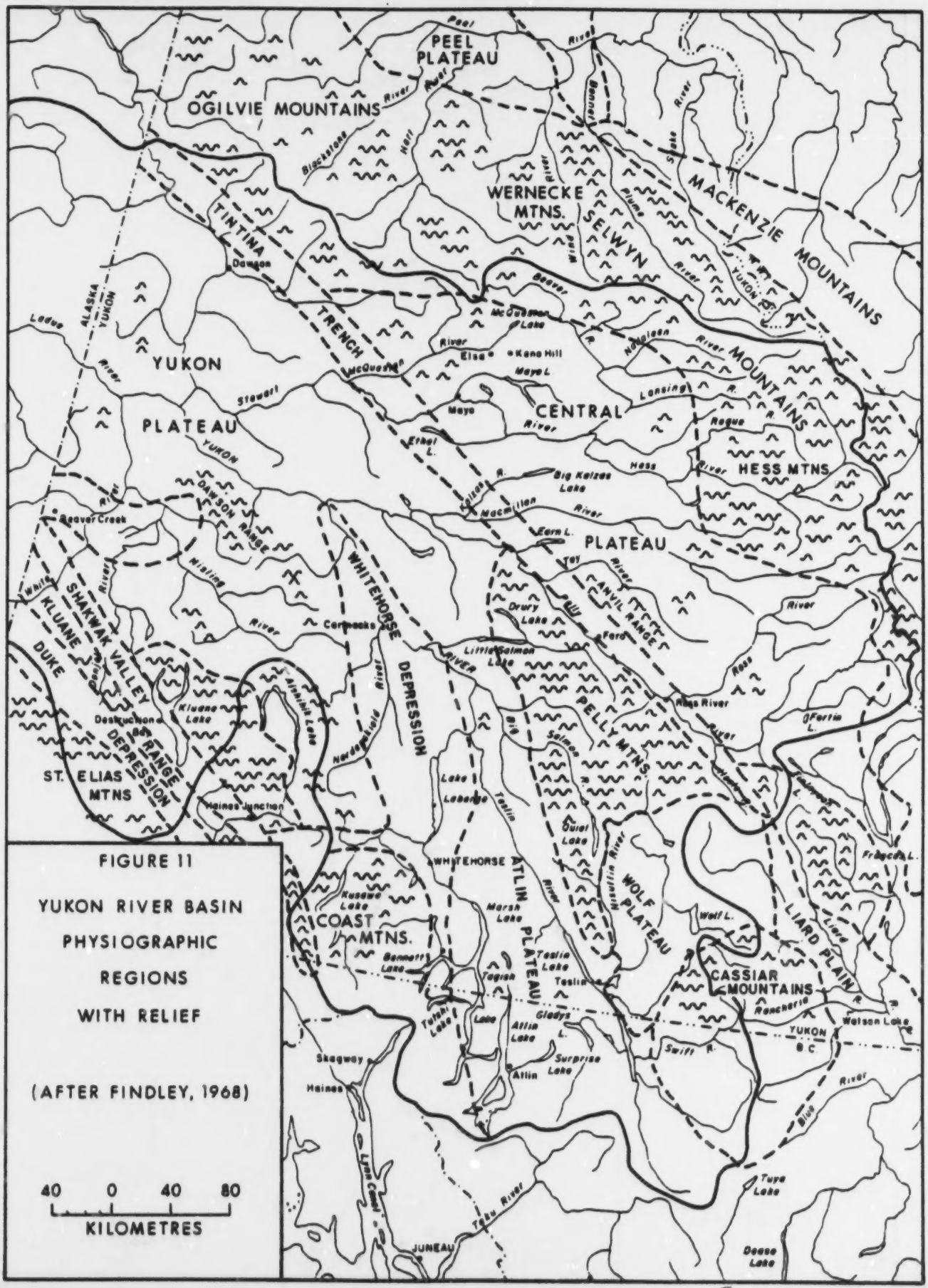


FIGURE 10

YUKON RIVER BASIN
PHYSIOGRAPHIC
SUBDIVISION

(AFTER BOSTOCK, 1965)

40 0 40 80
KILOMETRES


PEEL PLATEAU
OGILVIE MOUNTAINS
WERNECKE MTNS.
SELWYN MOUNTAINS
MACKENZIE MOUNTAINS
TINTINA TRENCH
YUKON PLATEAU
CENTRAL PLATEAU
HESS MTNS
WHITEHORSE DEPRESSION
SHAKWAK VALLEY
KLUANE RANGE
DUKE DEPRESSION
ST. ELIAS MTNS
COAST MTNS.
WHITEHORSE ATLIN PLATEAU
PELLY MTNS
WOLF PLATEAU
CASSIAR MOUNTAINS
LIARD PLAIN
ANVIL RANGE
DAWSON RANGE
Dawson
Mayo
Elsa
Keno Hill
Beaver Creek
Carmacks
Drury Lake
Little Salmon Lake
Destruction Bay
Kluane Lake
Haines Junction
Whitehorse
Marsh Lake
Tagish Lake
Atlin Lake
Atlin
Surprise Lake
Teslin
Teslin Lake
Gladys L.
Watson Lake
Ross River
Frances L.
Wolf L.
Skagway
Haines
JUNEAU
Tuya Lake
Dease Lake
Yukon B.C.
FIGURE 11
YUKON RIVER BASIN
PHYSIOGRAPHIC
REGIONS
WITH RELIEF
(AFTER FINDLEY, 1968)
40 0 40 80
KILOMETRES

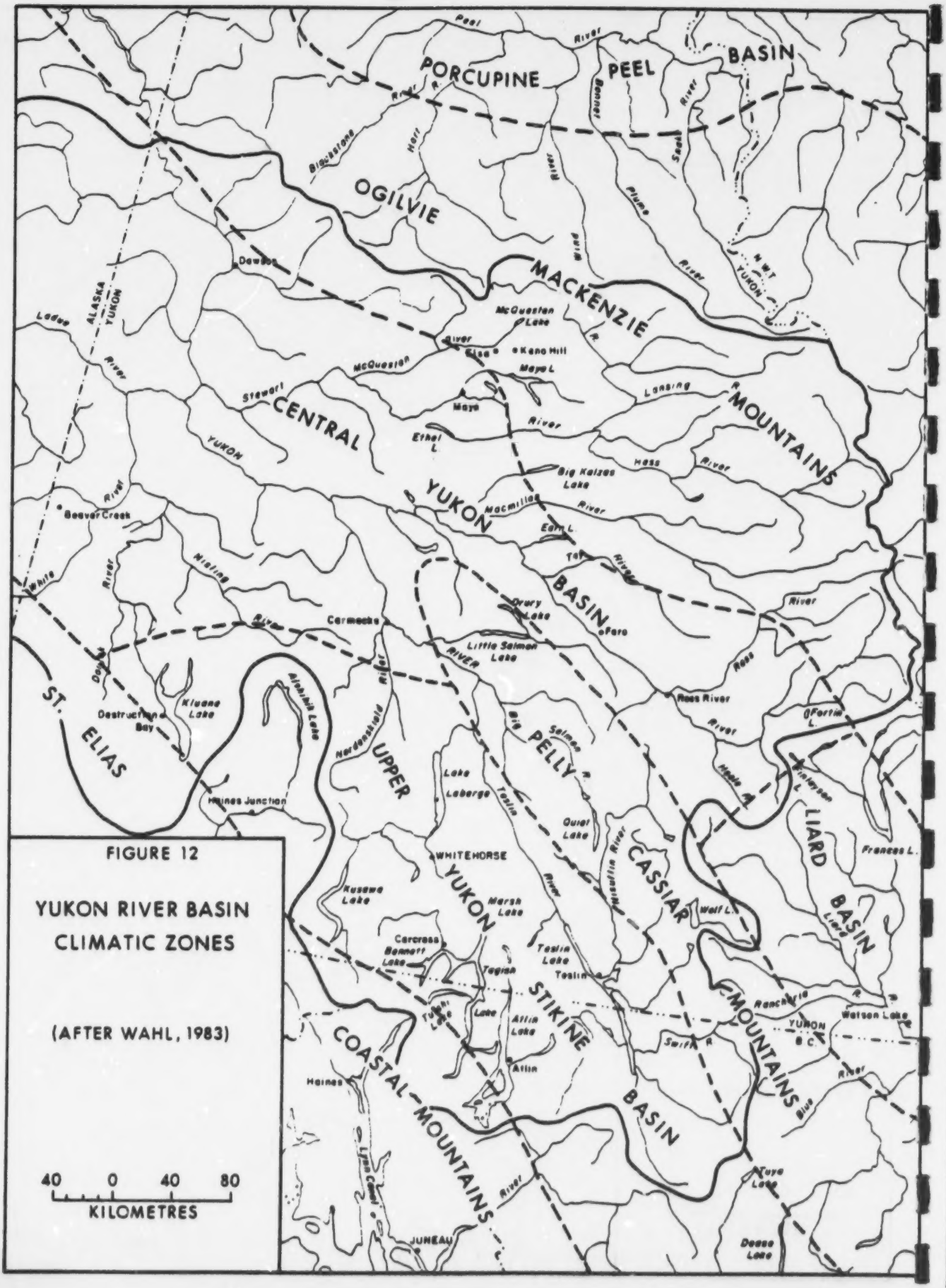


FIGURE 12

YUKON RIVER BASIN
CLIMATIC ZONES

(AFTER WAHL, 1983)

40 0 40 80
KILOMETRES

June and low flows in March and April. Smaller systems are susceptible to secondary summer rainfall peaks. This area is represented by three long term hydrometric stations with a range in runoff of 32 to 45 cm.

The Northeastern Mountains hydrologic region includes the lower reaches of the Ogilivie Mountains in the north and the Selwyn Mountains in the east. This area is within the broad Ogilivie-MacKenzie Mountain climatic zone which extends north outside the Yukon River basin to the Peel River. Since these mountains represent another major orographic barrier, precipitation amounts are high. Due to the elevation effect summers are cooler and winters are warmer than the adjacent plateau areas. The hydrologic response is characterized by spring snowmelt peaks with secondary rainfall peaks in the smaller basins. Mean annual runoff at the only long term station, Klondike River above Bonanza Creek, is 25 cm. A large portion of this basin is also within the Northern Interior zone.

2.12 Statistical Hydrologic Regions

The above regions represent physical hydrologic zones. Multivariate statistical analyses were used to attempt to statistically validate these regions. A cluster analysis was initially used to define rudimentary statistical groups. This technique forms groupings of stations based on a measure of association between them. The measure is based on correlation between variables and a measure of distance between cases. Initially individual stations are considered as separate clusters and at each subsequent step the two most similar groups are combined. Eventually all stations are contained within one group. Inspection of intermediate steps will disclose the more significant groupings.

A standard program from the Biomedical Computer Program Series was used for the analysis (Dixon and Brown, 1979). An attempt was initially made to include all available hydrometric data. However, the relatively short record lengths and seasonal periods of operation made hydrometric data collected by DIAND incompatible with the WSC hydrometric information. For this reason the statistical portion of the network assessment was carried out using WSC data only. Input parameters included selected sample statistics of the annual mean daily flow series divided by drainage area and a timing parameter. Specifically, mean annual daily low and peak flows divided by drainage area were utilized. The timing parameter represented the arithmetic mean of the dates of these events expressed in months. As an example, the date June 10 would be represented by the value: $6 + 10/30 = 6.33$. Only

stations with a minimum of ten years of record were used. Initial analysis included smaller record lengths in an attempt to maximize the input data. Poor results were obtained, however, using the smaller record lengths. This was also the case with some of the larger main stem stations. Because of their size these generally extend across several physiographic and climatic boundaries and therefore are not representative of a particular hydrologic unit. When station elimination was completed 39 data sets were available for analysis.

The analysis yielded two well defined groups with a third transitional group. These essentially correspond in area to include the stations draining the Coast Mountains as the most significant group, with the St. Elias stations forming the weaker transitional group. The third group consisted of the remaining stations. Too few stations represented the northeastern and southern mountains for a statistical definition, and these were combined with the north interior. The result was three rudimentary statistical groupings. It was then attempted to verify or amend the boundaries using multiple discriminant analysis.

Multiple discriminant analysis provides a means of statistically distinguishing between two or more distinct groups of data. The object is achieved by initially selecting a set of representative characteristics which are expected to differ between groups. These are then combined in such a way as to maximize the separation between groups so they are as statistically distinct as possible.

This technique is analogous to multiple regression analysis which relies on the selection of a set of characteristic parameters to best predict a dependent variable. Both techniques rely on a one way analysis of variance test to select the most appropriate variables. A stepwise procedure is employed in the discriminant analysis. This process begins by selecting the parameter for which the mean values among the various population groups are most distinct. The variable selected or entered is the one which yields the greatest value of the F statistic using the analysis of variance test. This process is then repeated to select a second discriminating parameter which in combination with the first improves the differentiation between groups. This is repeated with the remaining variables in successive steps. At each step variables already selected may be removed if they reduce separation when combined with the most recently entered parameter. The process is terminated when either all the variables are entered or the remaining variables no longer contribute to the discrimination. The end result is a discriminant function which may then be used to classify members.

As before, a standard program from the Biomedical Computer Program Series was used for the analyses with the same input parameters.

It was determined that too few stations existed in the St. Elias region to yield a statistical distinction between the Coast Mountains. These were combined to form the Western Mountain zone similar to the one initially delineated during the physical regionalization.

Zone boundaries were adjusted during subsequent analyses. Two statistically defined hydrologic zones were obtained with relatively high degrees of accuracy (Figure 13). The timing parameter was found to contribute most significantly to the discriminations by accounting for the greater part of the variance. Discrimination between the two groups was highly successful with 88 percent of the data classified correctly. The breakdown by region is 94 and 80 percent classified correctly for the Western Mountain region and the Interior region respectively.

Inspection of the provided plots shows considerable separation between the Western Mountain region and the Interior region. The discriminant analysis was successful with two distinct hydrologic groups being statistically defined for the Yukon River basin. It is probable that other hydrologic regions exist; unfortunately, due to the paucity of data in the northern and eastern parts of the basin, this could not be statistically validated. These two hydrologic zones will provide the basis for the evaluation of the hydrometric networks of the Yukon River basin.

2.2 Hydrometric Network Assessment

The objective of the analysis was to evaluate the data collection networks within the Yukon River basin with the intention of identifying data gaps and redundant stations for baseline purposes and site specific concerns. This was to be done within the framework of the existing networks as opposed to making recommendations for the establishment of a new network as if none had previously existed. To obtain a representative characterization of basin response it was essential to consider coverage of the complete range of drainage areas. Though no rigid breakdown of drainage areas was made in the analysis, differentiation was made between small, intermediate and large drainage areas. For reference purposes these roughly correspond to areas of less than 500 square kilometers, 500 to 1,500 square kilometers, and greater than 1,500 square kilometers respectively.

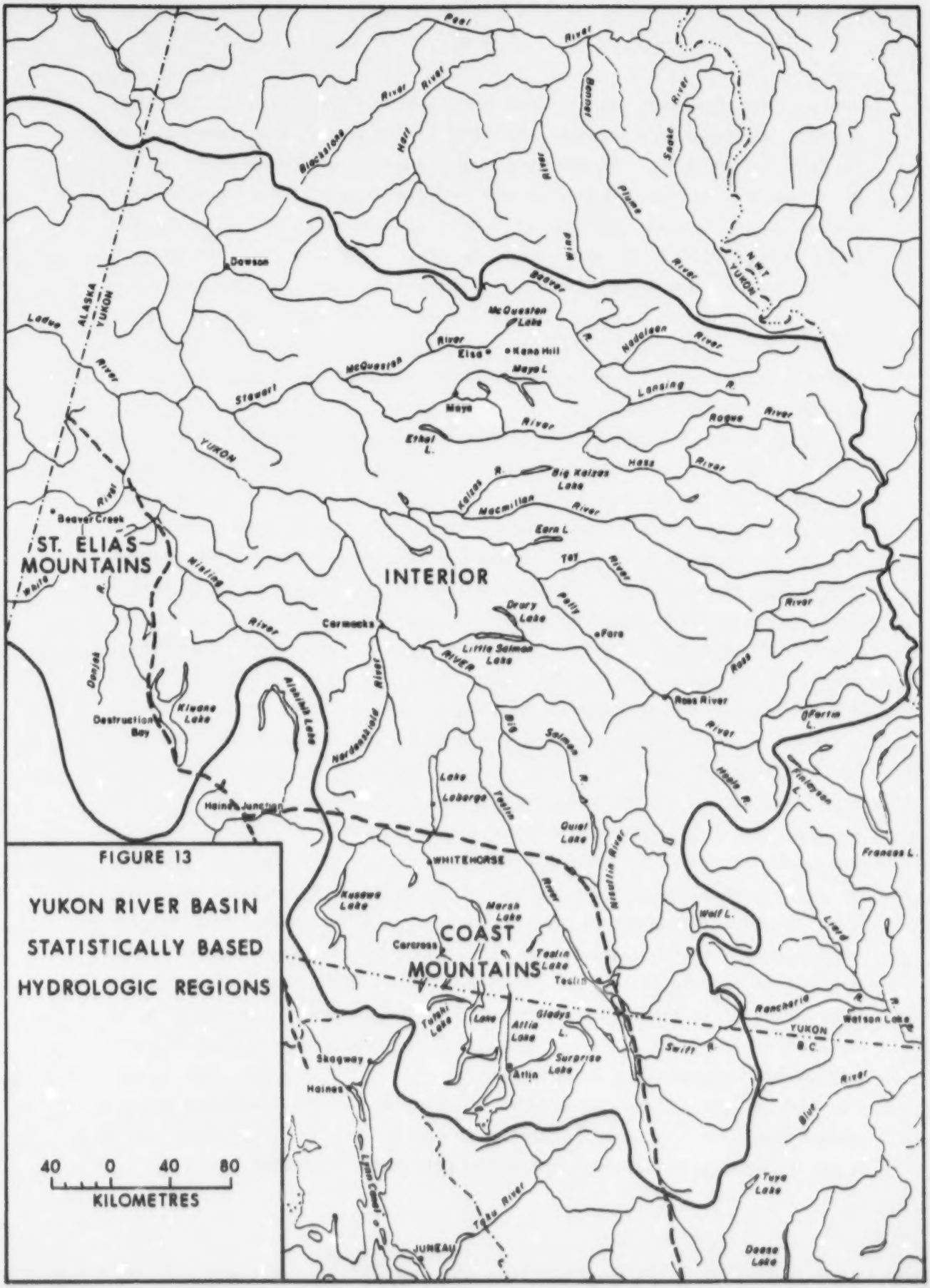
Consideration of coverage for small drainage areas is especially important since potential watershed response from these basins has been underestimated in the past. This is due to the inverse relationship between unit discharge and drainage area as a result of less storage capacity and a susceptibility to isolated climatic events. For this reason regional transfer techniques which were developed for larger drainage basins are not always applicable to the small areas. The utility of hydrometric information for small basins has only become evident during the last decade; therefore, long term network coverage of these basins is limited. For this reason it was desirable to assess the adequacy of the hydrometric networks operated by the Water Survey of Canada and the Yukon region of DIAND simultaneously. As mentioned above, however, the incompatibility of the networks due to variable station types and periods of operation did not permit this. Evaluation of the two networks was done independently, but the final recommendations were based on the combined adequacy.

The existing hydrometric networks were evaluated with the intention of identifying data gaps or potentially redundant stations. A particular hydrometric station may be discontinued if the streamflow characterization has been adequately defined or the station is no longer required for a site specific need. An additional justification for discontinuing a station is in the case where it is very difficult to operate from a logistical point of view.

2.21 Water Survey of Canada Hydrometric Network Assessment

The existing Water Survey of Canada hydrometric network was evaluated to determine if the stream flow response of a particular hydrometric station could be defined by a nearby station. A correlation analysis was used to determine the degree of interrelationship. A computer program developed by Lyons (1965) using a method described by Langbein (1960) was used for this study. The correlation is based on the logarithms of monthly hydrometric data which has had the mean of each month's discharge subtracted from it. The mean represents the mean of the logarithms of that particular month of the period of interest. This procedure standardizes the input data by accounting for the month to month variation. The correlation was carried out using the monthly mean discharge at the two stations of interest. Only monthly data that is common between the two stations was used in determining correlation coefficients.

The analysis was carried out using all available Water Survey of Canada


Peel River
Bonnet Plume River
Snake River
Blackstone River
Hart River
Dawson
ALASKA
YUKON
Ladue River
Stewart River
YUKON River
Beaver Creek
White River
Nisling River
Donjek River
Destruction Bay
Kluane Lake
Aishihik Lake
Haines Junction
Carmacks
Hootalinqua River
Little Salmon Lake
Drury Lake
Fort Selkirk
Pelly River
Ross River
Big Salmon Lake
Lake Laberge
Teslin River
Quiet Lake
WHITEHORSE
Kusawa Lake
Marsh Lake
Nisutlin River
Wolf L.
Frances L.
Liard River
Rancheria R.
Watson Lake
YUKON
B.C.
Swift R.
Blue River
Tuya Lake
Dease Lake
Teslin Lake
Tahkini Lake
Atlin Lake
Gladys L.
Surprise Lake
Atlin
Skagway
Haines
Lynn Canal
Taku River
JUNEAU
McQuesten Lake
McQuesten River
Elsa
Keno Hill
Mayo L.
Mayo
Ethel L.
Beaver R.
Haddigan River
Lansing R.
Rogue River
Hess River
Big Kalzas Lake
Kalzas R.
Macmillan River
Eora L.
Tay River
Fort L.
Finlayson L.
Hoole R.
Big Salmon R.
Carcross
Tesla Lake
Teslin
Ross

monthly streamflow data regardless of record length. Stations within the Alsek drainage basin were also included, since this area is almost totally enveloped by the Yukon River basin. As discussed above, due to the incompatibility of the DIAND and WSC hydrometric data, DIAND data was eliminated from the statistical components of this study. Analysis was carried out separately for each of the two statistically defined hydrologic regions as noted in Figure 13. The stations contained within the Western Mountains and Interior hydrologic regions are listed in Tables 14 and 15 respectively. In certain cases it was not possible to obtain a correlation for two particular stations. This occurred when one of the stations had only a few sample data. These stations were eliminated from further correlation analysis and are not listed.

The results in the form of a correlation coefficient matrix are presented in Tables 16 and 17. The correlation coefficient represents the measure of strength of linear correlation between variables. This strength is determined by the degree of response of one variable to a change in the others. The statistical significance of the correlation coefficient is a function of the size of the data set and the desired level of significance. Using this criteria at the 99 percent level of significance there are many highly correlated stations. As an illustration, a minimum correlation coefficient of 0.765 is required for a statistically significant correlation at the 99 percent level of significance, with N-12 degrees of freedom, where N is the total number of months in the overlapping data records, and a sample size of 20 (Johnson, 1976). As the data size increases, progressively smaller correlation coefficients are required for the relationship to be statistically significant.

Inspection of the correlation matrix for the Western Mountains shows that seven pairs of stations have correlation coefficients of 0.80 or greater. This value was arbitrarily chosen for discussion purposes. The overall correlation appears to be relatively high between many stations. These correlations are based on monthly data; however, and upon the consideration of specific periods or streamflow events, this correlation may decrease. This more detailed analysis was not carried out, and no specific recommendations are made for eliminating stations on this basis alone. It is recommended, however, that further analysis be conducted on these highly correlated stations. Doing so may identify certain stations for which information is duplicated by a nearby station.

Of the highly correlated stations draining the Western Mountains two pairs contain the Teslin River near Whitehorse. This station has been discontinued, but it is interesting to note that its record may be potentially reproduced.

TABLE 14 WATER SURVEY OF CANADA HYDROMETRIC STATIONS
WESTERN MOUNTAINS HYDROLOGIC REGION

STATION NUMBER	STATION NAME
08AA001	Aishihik River near Whitehorse
08AA003	Dezadeash River at Haines Junction
09AA006	Atlin River near Atlin
09AA007	Lubbock River near Atlin
09AA008	Pine Creek near Atlin
09AA009	Watson River near Carcross
09AA010	Lindeman Creek near Bennett
09AA011	Tagish Creek near Carcross
09AA012	Wheaton River near Carcross
09AA013	Tutshi River at outlet of Tutshi Lake
09AA014	Fantail River at outlet of Fantail Lake
09AA015	Wann River near Atlin
09AB001	Yukon River at Whitehorse
09AB008	M'Clintock River near Whitehorse
09AC001	Takhini River near Whitehorse
09AC004	Takhini River at outlet of Kusawa Lake
09AE001	Teslin River near Teslin
09AE004	Gladys River at outlet of Gladys Lake
09AF001	Teslin River near Whitehorse
09CA002	Kluane River at outlet of Kluane Lake
09CA003	Donjek River below Kluane River
09CB001	White River at Km. 1882

TABLE 15 WATER SURVEY OF CANADA HYDROMETRIC STATIONS
INTERIOR HYDROLOGIC REGION

STATION NUMBER	STATION NAME
09AB009	Yukon River above Frank Creek
09AD001	Nisutlin River above Wolf River
09AE003	Swift River near Swift River
09AG001	Big Salmon River near Carmacks
09AH001	Yukon River at Carmacks
09AH003	Big Creek near the mouth
09BA001	Ross River at Ross River
09BB001	South MacMillan River at Km 401, Canol Road
09BC001	Pelly River at Pelly Crossing
09BC002	Pelly River at Ross River
09BC003	Ross River below Faro Creek
09BC004	Pelly River below Vangorda Creek
09CD001	Yukon River above White River
09DA001	Hess Rier above Emerald Creek
09DC001	Mayo River near Mayo
09DC002	Stewart River at Mayo
09DC003	Stewart River above Fraser Falls
09DD002	Stewart River above Stewart Crossing
09DD003	Stewart River at the mouth
09DD004	McQueston River near the mouth
09EA003	Klondike River above Bonanza Creek
09EA004	North Klondike River near the mouth
09EB001	Yukon River at Dawson
09EB002	Yukon River at Stewart River
09EC001	Clinton Creek above Wolverine Creek

TABLE 16 WESTERN MOUNTAINS HYDROLOGIC REGION CORRELATION COEFFICIENTS

	08AA001	08AA003	09AA006	09AA007	09AA008	09AA009	09AA010	09AA011	09AA012	09AA013	09AA014	09AA015	09AB001	09AB008	09AC001	09AC004	09AE001	09AE004	09AF001	09CA002	09CA003	09CB001
08AA001	--	.743	.094	.147	.470	.431	.163	.437	.203	.206	.142	.083	.264	.417	.270	.180	.397	.326	.611	.242	.462	.078
08AA003	.743	--	.235	.308	.523	.523	.323	.531	.399	.492	.413	.375	.344	.508	.508	.458	.449	.510	.597	.355	.085	.199
09AA006	.094	.235	--	.477	.194	.360	.369	.424	.463	.603	.565	.568	.669	.314	.645	.701	.359	.332	.382	.341	.080	.035
09AA007	.147	.308	.477	--	.517	.681	.133	.789	.353	.325	.218	.201	.403	.636	.430	.417	.608	.667	.742	.215	.125	.145
09AA008	.470	.523	.194	.517	--	.628	.271	.558	.340	.406	.170	.327	.352	.522	.449	.287	.651	.702	.645	.315	--	--
09AA009	.431	.523	.360	.681	.628	--	.415	.699	.562	.599	.396	.510	.392	.629	.522	.529	.528	.597	.598	.293	--	--
09AA010	.163	.323	.369	.133	.271	.415	--	.021	.470	.674	.825	.753	.348	.324	.499	.494	.382	.350	.357	.207	.064	.070
09AA011	.437	.531	.424	.789	.558	.699	.021	--	.370	.302	.073	.135	.423	.646	.439	.181	.532	.636	.596	.058	--	--
09AA012	.203	.399	.463	.353	.340	.562	.470	.370	--	.711	.543	.594	.344	.521	.679	.656	.462	.626	.512	.188	.159	.039
09AA013	.206	.492	.603	.325	.406	.599	.674	.302	.711	--	.787	.836	.534	.473	.717	.747	.576	.685	.627	.206	.206	.102
09AA014	.143	.415	.565	.218	.172	.392	.823	.071	.542	.786	--	.889	.475	.274	.649	.653	.350	.402	.324	.319	.441	.054
09AA015	.082	.374	.569	.201	.327	.509	.750	.137	.591	.835	.888	--	.433	.297	.662	.698	.340	.502	.344	.206	.288	.125
09AB001	.264	.344	.669	.403	.352	.392	.348	.423	.344	.534	.476	.432	--	.278	.422	.521	.375	.301	.433	.270	.110	.112
09AB008	.417	.508	.314	.636	.522	.629	.324	.646	.521	.473	.274	.297	.278	--	.499	.421	.700	.656	.801	.136	.038	.173
09AC001	.270	.508	.645	.430	.449	.522	.499	.439	.679	.717	.647	.663	.442	.499	--	.919	.469	.499	.463	.285	.214	.164
09AC004	.180	.458	.701	.417	.287	.529	.494	.181	.656	.747	.652	.698	.521	.421	.919	--	.376	.516	.396	.331	.123	.014
09AE001	.397	.449	.359	.608	.651	.528	.382	.532	.462	.576	.348	.345	.375	.700	.469	.376	--	.777	.964	.185	.190	.102
09AE004	.326	.510	.332	.667	.702	.597	.350	.636	.626	.685	.401	.502	.301	.656	.499	.516	.777	--	.826	.128	.012	.113
09AF001	.611	.597	.382	.742	.645	.598	.357	.596	.512	.627	.325	.344	.433	.801	.463	.396	.964	.826	--	.181	--	--
09CA002	.242	.355	.341	.215	.315	.293	.207	.058	.188	.206	.320	.209	.270	.136	.285	.331	.185	.128	.181	--	.643	.231
09CA003	.462	.085	.080	.125	--	--	.064	--	.159	.206	.441	.288	.110	.038	.214	.123	.190	.012	--	.643	--	.632
09CB001	.078	.199	.035	.145	--	--	.070	--	.039	.102	.054	.125	.112	.173	.164	.014	.102	.113	--	.231	.632	--

TABLE 17 INTERIOR HYDROLOGIC REGION CORRELATION COEFFICIENTS

	09AB009	09AD001	09AE003	09AG001	09AH001	09AH003	09BA001	09BB001	09BC001	09BC002	09BC003	09BC004	09CD001	09DA001	09DC001	09DC002	09DC003	09DD002	09DD003	09DD004	09EA003	09EA004	09EB001	09EB002	09EC001
09AB009	--	.031	.216	.276	.721	.136	.123	.002	.268	.229	.066	.134	.532	.208	--	.174	.301	.285	.180	.274	.072	.277	.479	.626	.726
09AD001	.031	--	.799	.839	.759	.072	.498	.640	.706	--	--	.639	.742	.370	--	--	.272	--	.412	.012	.173	.293	.691	--	--
09AE003	.216	.799	--	.609	.613	.108	.421	.171	.556	.623	.668	.397	.648	.174	--	.327	.465	.336	.299	.200	.091	.223	.528	.717	.157
09AG001	.276	.839	.609	--	.671	.304	.439	.341	.678	.638	.709	.487	.711	.367	--	.464	.236	.492	.520	.101	.293	.450	.620	.856	.552
09AH001	.721	.759	.613	.671	--	.107	.369	.115	.577	.569	.573	.406	.879	.015	--	.349	.249	.404	.377	.120	.137	.260	.791	.854	.740
09AH003	.136	.072	.108	.304	.107	--	.328	.367	.542	--	--	.421	.409	.568	--	.260	.241	--	.439	.010	.440	.301	.544	--	--
09BA001	.123	.498	.421	.439	.369	.328	--	.457	.787	.864	.812	.834	.540	.553	--	.529	.097	.389	.476	.022	.250	.272	.580	.469	--
09BB001	.002	.640	.171	.341	.115	.367	.457	--	.444	--	--	.479	.307	.613	--	.352	.025	.323	.258	--	.168	.152	.332	--	--
09BC001	.268	.706	.556	.678	.577	.542	.787	.444	--	.836	.718	.883	.709	.539	--	.664	.410	.669	.693	.265	.303	.283	.745	.837	.699
09BC002	.229	--	.623	.638	.569	--	.864	--	.836	--	.723	.989	.697	--	--	.641	--	.565	.674	--	.222	--	.688	.767	.653
09BC003	.066	--	.668	.709	.573	--	.812	--	.718	.723	--	--	.680	--	--	.076	--	.053	.007	--	.036	--	.529	--	--
09BC004	.134	.639	.397	.487	.406	.421	.834	.479	.883	.989	--	--	.686	.402	--	.551	.484	.951	.553	.306	.272	.019	.738	--	--
09CD001	.532	.742	.648	.711	.879	.409	.540	.307	.709	.697	.680	.686	--	.372	--	.425	.152	.500	.536	.215	.205	.290	.843	.951	--
09DA001	.208	.370	.174	.367	.015	.568	.553	.613	.539	--	--	.402	.372	--	--	.673	.339	.635	.374	--	.528	.399	.634	--	--
09DC001	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.974	--	--	--	--	--	--	.908	--	--
09DC002	.174	--	.327	.464	.349	.260	.529	.352	.664	.641	.076	.551	.425	.673	.974	--	--	.906	.886	--	.584	.610	.580	.643	.672
09DC003	.301	.272	.465	.236	.249	.241	.097	.025	.410	--	--	.484	.152	.339	--	--	--	--	.927	.726	.015	.375	--	--	--
09DD002	.285	--	.336	.492	.404	--	.389	--	.669	.565	.053	.951	.500	--	--	.906	--	--	.943	--	.538	--	.653	.815	.669
09DD003	.180	.412	.299	.520	.377	.439	.476	.323	.693	.674	.007	.553	.536	.635	--	.886	.927	.943	--	.714	.678	.565	.676	.708	.620
09DD004	.274	.012	.200	.101	.120	.010	.022	.258	.265	--	--	.306	.215	.374	--	--	.726	--	.714	--	.401	.044	.591	--	--
09EA003	.072	.173	.091	.293	.137	.440	.250	.168	.303	.222	.036	.272	.205	.528	--	.584	.015	.538	.678	.401	--	.847	.457	--	--
09EA004	.277	.293	.223	.450	.260	.301	.272	.152	.283	--	--	.019	.290	.399	--	.610	.375	.565	.044	--	.847	--	.461	--	--
09EB001	.479	.691	.528	.620	.791	.544	.580	.332	.745	.688	.529	.738	.843	.634	.908	.580	--	.653	.676	.591	.457	.461	--	.983	.588
09EB002	.626	--	.717	.856	.854	--	.469	--	.837	.767	--	--	.951	--	--	.643	--	.815	.708	--	--	--	.983	--	--
09EC001	.726	--	.157	.552	.740	--	--	--	.699	.653	--	--	--	--	--	.672	--	.669	.620	--	--	--	.588	--	--

The large number of highly correlated pairs of stations within the Interior hydrologic zone is primarily due to the larger tributary streams which contain several hydrometric stations at intervals proceeding downstream. As would be expected, many of these are highly interrelated. The Pelly River has two active and one inactive stations, the Stewart River has four stations and the Yukon River has three, which are all relatively highly correlated at a monthly scale. The highly correlated pairs of stations for the two zones are listed in Tables 18 and 19.

2.211 Historical Site Specific Requirements

Prior to the last decade most hydrometric stations were established to meet a specific need. It was not until recently that the concept of a baseline network was conceived to provide information for planning and design purposes. For this reason the existing network is primarily a composite of a series of site specific stations. This is evident from the history of the network which refers to several developmental eras. Many of these stations are required for the reason they were initially established, while others serve more recent site specific needs or provide information for baseline purposes.

To determine if historical site specific stations are currently functional, all existing stations were examined. The majority of these stations contribute valuable information for baseline or site specific purposes, and in some cases stations contribute to both. The utility of one pair of stations is questionable. These are the Takhini River near Whitehorse and the Takhini River at the outlet Kusawa Lake. These stations were established in 1948 and 1952 respectively. The former was established for no apparent reason other than to gather information at a location which was readily accessible to an observer (Kreuder, 1980). The latter station was established as a result of an agreement with the United States to provide information for a study to assess the feasibility of diverting Yukon River headwaters into the Taiya River. Though these stations provide valuable baseline information, they are quite close in proximity, with inflows between the two stations increasing only by twenty percent. In addition, the correlation analysis indicates that the flows of these stations are highly related at the monthly scale.

TABLE 18 STATIONS WITH HIGH CORRELATION COEFFICIENTS - WESTERN MOUNTAINS HYDROLOGIC REGION

.801	Teslin River near Whitehorse	- McClintock River near Whitehorse
.964	"	- Teslin River near Teslin
.826	"	- Gladys River at Gladys Lake outlet
.835	Wann River near Atlin	- Tutshi River at Tutshi Lake outlet
.888		- Fantail River at Fantail Lake outlet
.823	Lindeman Creek near Bennett	- Fantail River at Fantail Lake outlet
.919	Takhini River near Whitehorse	- Takhini River at outlet of Kusawa Lake

TABLE 19 STATIONS WITH HIGH CORRELATION COEFFICIENTS - INTERIOR HYDROLOGIC REGION

.837	Yukon River at Stewart River	- Pelly River at Pelly Crossing
.951	"	- Yukon River above White River
.815	"	- Stewart River at Stewart Crossing
.983	"	- Yukon River at Dawson
.908	"	- Mayo River near Mayo
.856	"	- Big Salmon River near Carmacks
.883	Pelly River below Vangorda Creek	- Pelly River at Pelly Crossing
.989	"	- Pelly River at Ross River
.951	"	- Stewart River at Stewart Crossing
.834	"	- Ross River at Ross River
.974	Stewart River at Mayo	- Mayo River near Mayo
.906	"	- Stewart River at Stewart Crossing
.886	"	- Stewart River at the mouth
.879	Yukon River above White River	- Yukon River at Carmacks
.843	"	- Yukon River at Dawson
.927	Stewart River at the mouth	- Stewart River above Fraser Falls
.943	"	- Stewart River at Stewart Crossing
.864	Pelly River at Ross River	- Ross River at Ross River
.836	"	- Pelly River at Pelly Crossing
.812	Ross Creek below Faro Creek	- Ross River at Ross River
.847	Klondike River above Bonanza Creek	- North Klondike River near the mouth
.839	Nisutlin River above Wolf River	- Big Salmon River near Carmacks

2.212 Baseline Requirements

The Water Survey of Canada hydrometric network within the Yukon River basin provides reasonably adequate coverage of intermediate and large basins for baseline purposes. Coverage of small watersheds is less adequate, but for study purposes, these are discussed under the DIAND hydrometric section which follows. The available criteria for determining optimimum hydrometric guage density have been discussed. Though these have been used for comparison purposes, no particular criteria were adopted for this assessment. Instead, the Yukon River basin was assessed using the regional approach adopted above. It was desired to complete the existing network in such a way as to optimize areal coverage and provide the basis for transferring information to ungauged areas at any point within the network. Specifically, this was accomplished by ensuring that the physically derived hydrologic units as defined above had adequate coverage for a range of basin sizes. The Western Mountain region was subdivided into the St. Elias Mountain and Coast Mountain subzones. The adequacy of the hydrometric networks within each region is discussed below.

St. Elias Mountains

A station is required on the White River at the mouth. This area represents a large gap, primarily due to the logistical problems associated with establishing a hydrometric station on the braided channel of the White River. Little information for large basins is available for this area. If it is not possible to establish a station on the White River, flows could be determined by subtraction if a station were established below the White. This may be best achieved by reactivating the discontinued station, Yukon River below Stewart River. This station was proposed by Water Survey of Canada as a major stream station (Water Survey of Canada, 1975).

Coast Mountains

No major deficiencies.

Southern Interior Region

No information is available for larger basins in the upper Teslin area. A station located on the Teslin River at the inlet to Teslin Lake would provide baseline information for the Kawdy Plateau, which represents approximately half of the inflow to Teslin Lake. This station was proposed by Water Survey of Canada as a major stream station (Water Survey of Canada, 1975).

Northern Interior Region

The Northern Interior zone is the largest hydrologic region within the Yukon River basin and subsequently it is the most deficient in terms of baseline information. Generally the western and eastern boundary areas of this region contain the greatest gaps. A hydrometric station located at the mouth of the Nisling River would fill a large gap, providing information for the Nisling Range which is within an area of low precipitation. This station was proposed by Water Survey of Canada as a major stream station (Water Survey of Canada, 1975).

To the north, a station located at the mouth of the Sixty Mile River would provide information for intermediate sized basins draining the east facing slopes of the Klondike Plateau.

The nearby Ladue River, a large basin draining the same area, would likewise provide information for an under represented area. This station is of secondary importance since it likely exhibits a response similar to the Fortymile River.

In the eastern portion of this zone a station on the upper Pelly River would provide information for large basins draining the west facing slopes of the Pelly Plateau. A station located below Fortin Creek would serve this purpose. This station was recommended by Water Survey of Canada as a major stream station (Water Survey of Canada, 1975).

Southern Mountains Region

This region, the smallest hydrologic zone within the Yukon River basin, is relatively well monitored with respect to baseline coverage. One exception is the Jennings River, which flows in a northwesterly direction into Teslin Lake. This large basin represents a transitional area between the Southern Mountains and the Southern Interior hydrologic regions. Though its headwaters are in the Cassiar Mountains, approximately forty percent of the basin drains the lower elevation Kawdy Plateau. Basin response is expected to differ from the presently monitored Swift River to the north. A station at this location was recommended by Water Survey of Canada as part of the major stream network (Water Survey of Canada, 1975).

Eastern Mountains Region

The Eastern Mountains hydrologic region presently has the lowest density of gauging stations within the Yukon River basin. A large gap exists in the northeast corner of this zone within the Selwyn Mountains. This deficiency would be lessened with the establishment of a station on the Stewart River above Lansing River which would provide information for large basins (Water Survey of Canada, 1975). Of secondary importance, an additional deficient area exists in the Macmillan basin to the south. Though stations have been established in the headwaters and at the mouth, providing information for small and major stream basins respectively, no data is available for intermediate and large basins representing the transitional area between the northeast mountains and northern plateau. A station located on the North Macmillan River at the mouth would provide this transitional information. Draining the lower elevations of the Hess Mountains and portions of the Macmillan Plateau, basin response probably differs from the higher elevation Hess station.

2.213 Site Specific Requirements

As discussed above, this category consists of stations required both for future planning and design purposes and for current uses. The major developmental concerns have been identified. It is important that adequate long term hydrometric information be obtained to provide planning and design information for these. As mentioned, the most probable potential mining development areas are Macmillan Pass, Howards Pass and the Venus Mine area on near Carcross. Adequate hydrometric coverage currently exists for the Macmillan Pass area. These are provided by the Tischu River station, though which is in the Northwest Territories, is representative of streamflow response within the Macmillan Pass area, and the upper Macmillan station, which provides information for intermediate size basins. Several DIAND seasonal hydrometric stations located along the North Canol Highway provide information for small basins. No streamflow information is available for the Howards Pass area, though information from Macmillan Pass and from the Tungsten area may be transferrable. Streamflow data is required to provide the basis for the design of stream crossings and other hydraulic structures. Adequate representation of larger basins is currently available or has already been recommended. Information for small to intermediate size basins, however, is required. This information would be provided in part by a hydrometric station established on the upper Pelly system near Howards Pass.

Since the Venus Mine development was already at the production stage little need for additional design information is envisioned. Several existing hydrometric stations in the vicinity of the development, however, would provide any required information for design purposes.

Of the four proposed major hydroelectric developments, all but one currently have adequate hydrometric coverage. These are the mid-Yukon, Teslin and Pelly (Granite) projects. No upstream information is available for the Pelly (Hoole) proposal, though some historical information may be approximated by subtracting the Ross River from the recently discontinued Pelly River at Ross River station. An upstream station would supplement the information already available. The proposed baseline station, Pelly River below Fortin Creek, would provide this information.

The most promising small scale proposed hydroelectric developments, which are intended to meet increasing power demands prior to the construction of a major development are Squanga Creek, Atlin River and Atlin Lake. A lake level gauge and a metering cross section at the outlet of Squanga Creek would provide information on the hydrologic regime of the system.

Since Atlin Lake is in the headwaters of the Yukon River basin system no major tributaries provide inflow to the lake. Inflows are provided by small streams and direct runoff. Hydrometric stations exist on the Lubbock River flowing southwards into Atlin Lake and historical information is available for Surprise Creek. These may provide adequate information to characterize inflows. Additional stations provide lake elevations and outflows from the system.

Insufficient winter low flow information is available for the proposed North Klondike hydroelectric development; however, since this development may go forward in the near future using synthetic information, it is unlikely that there is sufficient lead time to establish a station.

Site specific requirements for current operational needs are also deficient in certain areas. It has become evident recently that the Marsh- Tagish-Bennett Lake system behaves as more than a single lake, which is generally the way it is treated. A recent study (Water Planning and Management Branch, 1982) indicates that at certain stages at least two separate lakes exist. Unfortunately, there is insufficient hydrometric data to define the existing relationships. Since Marsh Lake is regulated to provide storage for the Whitehorse Rapids hydroelectric plant, this data would provide valuable information for system operation.

In order to adequately define the existing relationship between the individual components of the Marsh-Tagish-Bennett system it is necessary to establish a water level station on Tagish Lake and relate it to a metering cross section on the Six Mile River, providing information on the outflow of Tagish Lake. A metering cross section is also required at the outlet of Bennett Lake, which could be related to the Bennett Lake gauge.

Real time hydrometric data would provide valuable input information for operational flood forecasting. The two major areas of concern are the Pelly and Stewart Rivers above the communities of Ross River and Mayo, respectively. Stations already recommended to provide baseline information would also fulfill the flood forecasting needs, especially if these provide real time information.

Real time data capabilities would also greatly increase the utility of existing stations on regulated lakes and reservoirs. Specifically, real time data from the Marsh Lake station would improve system operation of the Whitehorse Rapids hydroelectric plant.

2.22 DIAND Hydrometric Network Assessment

Due to the incompatibility of the respective data provided by WSC and DIAND hydrometric networks it was not possible to carry out a statistical analysis on the DIAND network. The network was evaluated to determine its adequacy for baseline purposes using the hydrologic regions developed with the WSC information. No correlation analysis was carried out to determine the interrelationship between component stations making up the network. Instead, each hydrologic region was assessed to insure an adequate distribution of stations throughout physiographic and climatic subregions. The site specific components were assessed in a fashion similar to the WSC network.

2.221 Baseline Requirements

As with the WSC network, the majority of the stations comprising the DIAND hydrometric network likewise were established to meet site specific needs. The network has seen considerable expansion over the last few years and has grown to an almost unmanageable size. As noted, the DIAND network was originally established to provide short term project oriented information on flow characteristics of streams from small drainage areas. The network has expanded considerably,

however, through requests by private and other other agencies for data to meet development pressures.

Much of the highway system in the Territory and the Yukon River basin has hydrometric data with record lengths in excess of five years. Though the objectives of the network were initially project oriented, these have evolved with time to follow the objectives of a data collection agency such as Water Survey of Canada. This has occurred without any formal redefinition of goals. A well planned, long term, hydrometric network on small basins would provide invaluable baseline information for future development. Very little long term information of this type is available, and in the past little thought was put into the design of small hydraulic structures such as culverts and other small stream crossings. These have been simply estimated. It is now evident that these can be more vulnerable to peak flow events than structures on larger systems.

The necessary design information can be provided by certain key stations which, when optimally located with respect to physiographic and climatic characteristics within their respective hydrologic regions, will represent the streamflow characteristics of the area. Secondary stations will characterize the areal variability of runoff in transitional areas. The historical network with its many relatively long term stations has the potential of providing the framework for the proposed network.

Evaluation of the historical network to select stations to make up the long term baseline network proceeded on a regional basis using the hydrologic regions previously defined. The historical network was evaluated with the intent of selecting a list of primary and secondary stations for the baseline network. Selection was based on a consideration of record length and quality, and location with respect to neighboring stations and hydrologic boundaries. This resulted in the deletion of 24 stations which were thought to provide redundant or poor quality information. This does not include the recent North Canol Highway stations which were established for a specific project. Elimination of these stations leaves the proposed network at 54 percent of the size of the 1982 network. A list of stations recommended to make up the baseline network is presented in Table 20. Since these are located on the existing highway networks of the basin they will also provide information immediately for site specific uses associated with the highway. It is stressed that the list is based on physical characteristics only and when sufficient data is available a statistical analysis should be carried out. It may then be possible to delete several more stations without the loss of information. The

TABLE 20 PROPOSED DIAND BASELINE HYDROMETRIC NETWORK

STATION #	STATION NAME	AREA	KM	YEARS RECORD
30AE002	Big Creek	Alaska Highway	1084.8	1978 -
29AE003	Partridge Creek	Alaska Highway	1184.9	1978 -
29AB001	Judas Creek	Alaska Highway	1402.7	1979 -
29AC004	Ibex River	Alaska Highway	--	1979 -
29AC001	Mendenhall Creek	Alaska Highway	1557.9	1976 -
29CA005	Christmas Creek	Alaska Highway	1687.8	1979 -
29CB002	Dry Creek #2	Alaska Highway	1905.0	1976 -
29CB006	Edith Creek	Alaska Highway	1844.2	1976 -
29CB004	Snag Creek	Alaska Highway	1945.6	1978 -
29BA002	180 Mile Creek	North Canol Road	295.8	1975 -
29BB001	Boulder Creek	North Canol Road	387.0	1977 -

proposed baseline network will consist exclusively of water level recorder stations.

As mentioned above, the hydrometric network operated by DIAND evolved from a few stations which were established to provide miscellaneous information primarily for culvert design and fisheries concerns. The network developed with additional requests for data from government and other agencies. Initially the collected data were intended to provide rudimentary estimates of streamflow for areas where previously none existed. It soon became evident, however, that there was a real need for this information and that long term records were required for statistical consideration. This was noted by DIAND, who sought to provide monitoring of selected stations on a continuing basis. This information was reduced and archived by DIAND, who also distributed the information in a published format annually.

Distribution was generally limited to those agencies and individuals which initially requested the information. Additional requests for the publication as it became better known resulted in an increased distribution. Because of increasing requests for the publication annually, it was felt that more potential users would be found if the publication had a wider distribution.

It was hoped that this could be achieved through inclusion by Water Survey of Canada in their annual publication. Water Survey of Canada policy dictates, however, that data which differs from the WSC national standard may not be included in this publication. For the information to meet WSC standards considerable additional expense and time are required to both physically upgrade the stations and to routinely reduce the raw data.

Since data collection is not a primary responsibility of DIAND, expending the additional resources to have the information more widely distributed cannot be justified. At the same time, it is desirable that those stations which are recommended to provide long term baseline information be consistent with WSC national standards. The most cost effective method of achieving this end would be for WSC to absorb these stations into their hydrometric network. Doing so would insure the availability of the necessary consistent, long term baseline information while allowing DIAND to concentrate on other tasks. Discussion has been initiated which will hopefully lead to the establishment of hydrometric stations in the small basins identified for baseline purposes. These will be operated by DIAND until such time as WSC absorbs them into their network.

2.222 Site Specific Requirements

The historical DIAND network was evaluated from a site specific point of view to determine if a particular station was required for a specific purpose. Similar to the WSC hydrometric network, it was found that though many stations were no longer needed for the original reason they were established, these provide valuable baseline information or more recent site specific information. Table 21 lists those existing stations which provide information required for site specific needs. These are primarily associated with the placer mining industry, though other concerns are represented as well.

The two North Canol Highway stations provide design information for realigning and upgrading the highway. However, at such time as the proposed baseline stations are incorporated into the WSC network it will no longer be cost effective for DIAND to maintain these. Similarly, the remaining stations will be discontinued when no direct utility exists for the data.

Site specific requirements for the proposed major developments have been covered under the WSC section. DIAND's future role with respect to hydrologic monitoring should be limited to site specific requirements or surveillance purposes, and to provide basic short term design information for proposed developments. This should not evolve to become a systematic program with a continually expanding network. Stations which are found to duplicate information or likewise no longer provide useful site specific data should be discontinued.

With the increasing popularity of small hydroelectric projects DIAND has been approached to provide both technical and logistical assistance. It has been suggested that DIAND adopt a watershed studies approach for such projects, and provide the necessary instrumentation and technical expertise to define basin response to measured rainfall or snowmelt inputs. Also, since low flows are often the limiting factor for small hydroelectric developments, requests have been made to obtain winter low flow measurements. This parameter is extremely difficult to measure on small streams without the use of control structures. For the purpose of characterizing winter low flows accurately, it may be necessary to use control structures.

TABLE 21 PROPOSED DIAND SITE SPECIFIC HYDROMETRIC NETWORK

STATION #	STATION NAME	AREA	KM	YEARS RECORD
29AC003	Unnamed Creek	Alaska Highway	1492.0	1979 -
29CA003	Burwash Creek	Alaska Highway	1776.2	1978 -
29BC003	Vangorda Creek	Faro Area	--	1977 -
29BB002	South MacMillan #2	North Canol Road	438.6	1975 -
30HA001	Dale Creek	North Canol Road	--	1977 -
29DD002	Clear Creek	Dawson Area	--	1979 -
29CD001	Thistle Creek	Dawson Area	--	1980 -
29DD003	Scroggie Creek	Dawson Area	--	1981 -
29EB004	Henderson Creek	Dawson Area	--	1981 -
29EB001	Sixty Mile River	Dawson Area	--	1977 -
29EB002	Big Gold Creek	Dawson Area	--	1979 -
29EC001	Clinton Creek	Dawson Area	--	1978 -
29EB003	Matson Creek	Dawson Area	--	1979 -

3.0 METEOROLOGICAL NETWORK

The Meteorological Service of Canada was established in 1871 under the Department of Marine and Fisheries, providing selected weather and magnetic observations (Atmospheric Environment Service, 1979). In 1876 responsibilities increased to provide storm warnings for the Great Lakes and Atlantic coast shipping lanes. In the early twentieth century weather forecasting and storm warning capabilities expanded across southern Canada. Improved communication led to the establishment of stations in northern Canada since data could be transmitted to collection centers in the south. In 1936 the Meterorological Service became a division of the Air Services Branch of the Department of Transport. Since that time there has been an increasing demand for meteorological services brought about by escalating property and income losses caused by climate related events, the degradation of the natural environment, and improved forecasting capabilities. In 1970 all matters dealing with meteorology were consolidated and transferred to the Department of Environment under the Atmospheric Environment Service. In the last decade the level of service has expanded as a result of a growing awareness of the importance and function of meteorological services and improved technology, which provided an expanded communication network and improved data processing capabilities.

3.01 History of the Meteorological Network in Yukon Territory

The growth of the meteorological network in Yukon Territory closely corresponds to the development of the region with three main growth periods. The first stations were established in the late nineteenth century and early twentieth century as a result of discovery of gold and a subsequent population growth. The next major developmental era came with the second world war to support the northwest staging route to Alaska and Russia. This generally improved transportation to and within the Territory and led to an increase in mining activities in the 1950's and the subsequent third growth period.

Miscellaneous meteorological data were obtained and informal records were kept during the period of early exploration in the middle 1850's and the first recognized stations were established as a result of the Klondike gold rush. The

first formal meteorological station to have data published by the Canadian Meteorological Service in the Yukon River basin was at Tagish in 1900. Tagish, at the headwaters of the Yukon River, was established as a checkpoint along the water route to Dawson.

A station established at Dawson in 1901 is currently operating and provides the longest continuous record in the Basin. Atlin saw the establishment of a station in 1906. However, it was discontinued in 1946 and a continuous program was not established at that location again until 1966. Several stations providing intermittent records were established in the early twentieth century to support primarily gold mining operations. A station was established at Carcross in 1909 and provided data until 1960, and was again reopened in 1972. A station at Swede Creek in the Dawson area operated between 1919 and 1929. The Mayo station, which is currently operating, was established in 1925. A station at Engineer in the Atlin area provided data between 1926 and 1929.

The Northern British Columbia and Yukon meteorological network expanded extensively during World War II to provide weather information for the Northwest Staging Route which consisted of both an air and land corridor for ferrying supplies to Alaska and Russia. Six stations within the Yukon River Basin and three nearby were established during this period. The majority of these operated for a short period only with the exception of Snag, which provided data between 1943 and 1966, and Teslin, which is currently operating. The nearby long term stations include Aishihik, Haines Junction, Swift River and Watson Lake. Though intermittent information is available for Whitehorse since 1905, continuous monitoring did not begin until 1941 when a station was established in downtown Whitehorse. In 1942 the station was relocated at the present location at the airport. An additional station was established in Riverdale in 1959 after it was determined that the airport information was not representative of the more extreme temperature regime in Riverdale.

A further period of expansion took place during the 1950's and 1960's in response to a greater accessability to the world markets provided by the White Pass Railway and the Alaska Highway transportation corridors. This was noted and the potential of developing the mineral resources of the territory was assessed. This led to the further expansion of the highway network to facilitate the extraction of the mineral resources. The communities of Dawson and Mayo were linked with Whitehorse. The South Canol Highway was open to Ross River, and the Robert Campbell Highway linked Watson Lake and Ross River with the Nahanni Range

Highway to Tungsten. Long term stations were established at Carmacks, Elsa, and Fort Selkirk during this period, and near Faro in 1967. Short term stations were established at Clinton Creek and Faro in 1966, and at Howards Pass in 1977.

The expansion of the highway network discussed above required the establishment of a series of camps to provide general maintenance for the highways. In addition to those already located in existing communities, new camps were constructed in remote locations which could not be served from existing centers. These highway camps provided the framework for further development of the network, providing data for remote areas which previously were devoid of this information. The 1960's and 1970's saw the establishment of long term stations at Johnsons Crossing, Ross River, Burwash Landing, Beaver Creek, and several remote locations on the North and South Canol, Haines, Alaska, Klondike and Dempster Highways. The Burwash Landing station was established to replace Aishihik, which was discontinued the same year.

This period saw Yukon enter the age of automation with the recording rain gauge. This type of instrumentation was essential for the derivation of intensity and duration curves and other information associated with frequency of occurence. Yukon's first recording rain gauge was located at Whitehorse in 1959, followed by installation in many communities. Recording rain gauges were installed in Carmacks and Johnsons Crossing in 1963, in Haines Junction in 1964, Fort Selkirk in 1965, Teslin in 1967, Watson Lake in 1969, Burwash and Faro in 1974, Mayo and Dezadeash in 1975, and Dawson airport in 1976.

Three other developmental phases took place during the 1970's. The year 1969 saw the beginning of a precipitation gauge network which was designed to go unattended for relatively long periods of time. These consisted of Sacramento storage gauges and Fischer-Porter recording gauges which could go unserviced for periods of up to three or four months. The first gauge to become part of this network was a Sacramento gauge which was located on the Dempster Highway near the divide between the Yukon and Peel Basins. In 1972 a Sacramento gauge was installed at Macmillan Pass, also a boundary area. In 1973 a remote station accessible by air only was established on the Firth River. The first remote stations of this type to be established in the Yukon River Basin was a Fischer-Porter gauge installed at Sheep Creek near Kluane Lake in 1974. To date several more stations of the two types have been established in both road and air accessible only locations.

A relatively dense cooperative weather network was present within the St. Elias Mountains as part of the Ice Field Ranges Research Project carried out jointly by the Arctic Institute of North America and the American Geophysical Society, which is a study to document the total environment of the St. Elias Mountains. Five meteorological stations were operated during the 1960's to meet study objectives, and these provided information during the summer months only. Most of these are at relatively high elevations, with one station at the 5,370 meter elevation.

In 1974 a program was initiated to place official meteorological instruments in fire lookout towers througout the territory. Instruments which were generally purchased by DIAND consisted of both temperature and rainfall and were treated as observer stations ing the fire season only. Sacramento type storage gauges with Alter shields for year round observations were collocated by AES as part of the remote network. Eight fire towers were instrumented in this fashion.

In 1976 the Water Resources Division of DIAND foresaw a need for an expanded precipitation and evaporation data base. It was determined that precipitation characteristics were highly variable from one basin to another; therefore it was desirable to obtain additional information in order to better understand the relationship between precipitation and streamflow in these hetrogenous basins. Likewise, evaporation data was very limited, and it was suspected that the available data did not adequately represent the existing variation. The establishment of additional remote stations was viewed as the first step towards a more complete representative climate station network.

Of specific concern, additional information was required for the derivation of design flow estimates as well as other uses for more remote regions of the Territory. It was therefore decided to collocate recording precipitation gauges in basins which presently possessed recorded streamflow data. Doing so would permit the transfer of this design information to nearby ungauged basins. DIAND's additional data requirements could not be absorbed by AES as part of their national network. DIAND did not wish to duplicate the expertise provided by AES, therefore, several alternate means of dealing with this network expansion were pursued. Discussions between the various concerned agencies spanned several years during which time DIAND Water Resources established and serviced six Fischer-Porter sites within the Territory and provided AES with the data for reduction and publication. Within the Yukon River Basin these include a station on the Hess River collocated with the Water Survey Canada hydrometric station; a station at Sheldon

Lake on the North Canol Highway, and a station at Montana Mountain near Carcross. An informal agreement was established through a Memorandum of Understanding in 1979, where AES supplied the manpower to maintain the expanded network on a cost recoverable basis. DIAND transferred funds to AES on an annual basis to cover a technician's salary, operating and maintenance costs, capital requirements, and air charter expenses.

In addition to the Fischer-Porter stations mentioned above evaporation pans were installed at Mayo and Watson Lake, and a snow course network was to be established.

Four additional DIAND Sacramento storage gauges were installed as a part of this program between 1980 and 1982. These included gauges at Sekulman Lake in the Aishihik Basin, the Nisutlin-Liard Divide in the Pelly Mountains, Keno Hill in the Stewart Basin and the Hyland River drainage outside the Yukon River Basin. Discussions between the respective departments leading to a formalized Memorandum of Understanding took place with little progress for several years since the informal agreement was implemented. In 1983, in response to the federal government restraint policy, AES, like other departments, was required to reduce it's person-year utilization. Since one of the two technical positions in the Whitehorse office was filled with an unsupported person-year this position was withdrawn, subsequently terminating the agreement between DIAND and AES for support of the DIAND precipitation and snow course network. Assistance on a limited basis is still provided where DIAND requirements can be included in the AES schedule. Since DIAND has also been subjected to staffing reductions, maintenance of existing programs may be in jeopardy. In any case, future development of these networks can only be curtailed.

The historical meteorological network is noted in Figure 14.

3.02 Atmospheric Environment Service Policy

In 1978 AES carried out studies which produced a policy statment outlining the levels of service which the federal government should provide under its mandate (Atmospheric Environment Service, 1979). AES objectives in response to national needs are:

1) to reduce the effects of adverse meteorological conditions, thereby preserving the safety of life and property;

2) to maximize the effects of meteorological conditions in support of socio-economic programs;

3) to maintain the quality of the natural environment by limiting the harmful effects of man's activities on the atmosphere.

The nature of the atmosphere and meteorological processes is such that many factors affect the provision of meteorological services. Not only does the atmosphere continuously interact with the land and water surfaces of the earth, but its physical dimensions also continuously vary both temporally and spacially, necessitating the consideration of various scales. These scales must be categorized before it is possible to establish a specific meteorological network. In order to describe, explain and predict atmospheric changes the level of accuracy and the time frame desired must be defined.

Meteorological processes vary from the micro scale such as isolated storm events which may have spatial dimensions of one kilometer and temporal dimensions of a few minutes to the planetary scale such as jetstream patterns with spatial dimensions of thousands of kilometers and temporal dimensions of days and weeks (Atmospheric Environment Service, 1979). For operational purposes at the micro and small scale it is necessary to have the capability to obtain a set of observational data every few minutes or hours throughout the area concerned. At planetary and large scale this information is required once an hour to every several hours on a regional or hemispherical level.

3.03 Meteorological Service Zones

A zone concept has been developed by AES to determine the level of service to be provided for any given location in Canada (Atmospheric Environment Service, 1979). Three meteorological service zones have been designated for the country.

Zone 1

Zone 1 encompasses areas where the safety and security of life and property have the greatest impact; areas where user groups have the greatest socio-economic benefit potential for meteorological services; and areas where the environment needs greatest protection. Certain isolated areas outside the specified

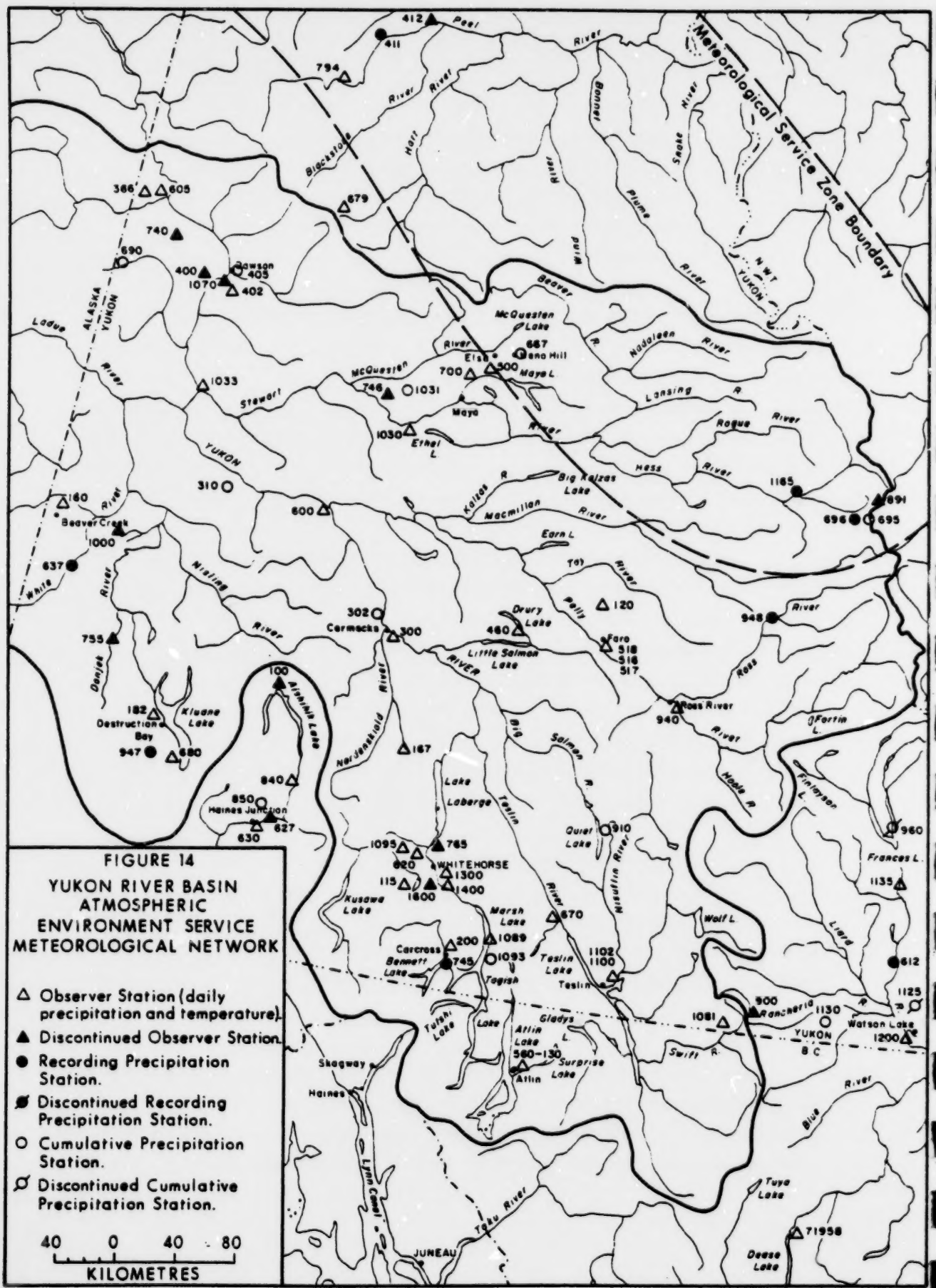


FIGURE 14

YUKON RIVER BASIN
ATMOSPHERIC
ENVIRONMENT SERVICE
METEOROLOGICAL NETWORK

- △ Observer Station (daily precipitation and temperature).
- ▲ Discontinued Observer Station.
- ● Recording Precipitation Station.
- ⌀ Discontinued Recording Precipitation Station.
- ○ Cumulative Precipitation Station.
- ⌀ Discontinued Cumulative Precipitation Station.

40 0 40 80
KILOMETRES

boundaries are operationally classified as Zone 1. These include urban population centers with populations exceeding 1,000 residents, designated air terminals, military bases, harbours, air and marine transportation routes, and resource development areas.

Zone 2

Zone 2 encompasses areas where user groups collectively have a socio-economic benefit potential for meteorological services. This includes agricultural regions, parks and recreation areas, habitats of endangered species, commercial fishing and renewable resource regions.

Zone 3

Zone 3 encompasses areas where user groups are widely scattered.

As illustrated in Figure 14, approximately 75 percent of Yukon Territory and most of the Yukon River basin is within Zone 2 with the remainder in Zone 3. It is emphasized that these zones are intended to act as a rough guideline only.

The design specifications with respect to density and frequency of reporting are based on guidelines developed by the World Meteorological Organization. These guidelines are based on studies of areal variation of precipitation for various physiographic and climatic zones (WMO, 1969). The range in the value of the minimum acceptable gauge density accounts for difficult conditions resulting from a small population density, a poor communication network, and other economic reasons.

3.1 Meteorological and Climatological Networks

Recorded meteorological data has many uses within the Yukon River basin. It is used for weather forecasting, for aviation and other transportation services, and for the management of natural resources with respect to planning, design and operation. Most activities dealing with the sub-Arctic environment must give fundamental considerations to the available climatic records.

For the purpose of this study the Yukon River basin meteorological network is made up of several component and subcomponent networks which are classified according to the type and frequency of data reported. The classification scheme generally follows a format used by AES. A particular station may be used for more than one purpose; therefore it may be included in more than one network.

3.11 Meteorological Station Network

The meteorological network is used primarily for weather forecasting purposes at the large or mezzo scale. Within the meteorological network are the synoptic, hourly and upper air component networks.

3.111 Synoptic Meteorological Network

The synoptic network adheres to WMO regulations with simultaneous world-wide observations taken four times daily. The information collected by this network presents a comprehensive picture of weather conditions for national and international forecasts. Table 22 provides a listing of the active stations comprising the synoptic network and their locations are noted in Figure 15. Selected stations outside the Yukon River basin are also shown since information provided by these stations may be applicable to the basin. Measured parameters include temperature, precipitation, wind, sky conditions, visibility, atmospheric pressure, and humidity. According to AES guidelines (Atmospheric Environment Service, 1975) these should have a maximum radius of influence of 150 kilometers in Zones 1 and 2 with an optimum radius of 75 kilometers if economic and other conditions permit. A maximum radius of 250 kilometers is recommended for Zone 3 stations.

3.112 Hourly Meteorological Network

The hourly meteorological network provides weather information at a local level, in addition to serving regional and national needs. This information is primarily used for recording and forecasting weather for aviation purposes. Reports are prepared hourly at primary stations, and less frequently, but on a fixed schedule, at secondary stations. In addition to temperature and precipitation, the primary stations of this network monitor wind, cloud cover, visibility, atmospheric pressure and humidity. Though all secondary stations monitor precipitation and temperature, some of the remaining parameters may not be included. Within the

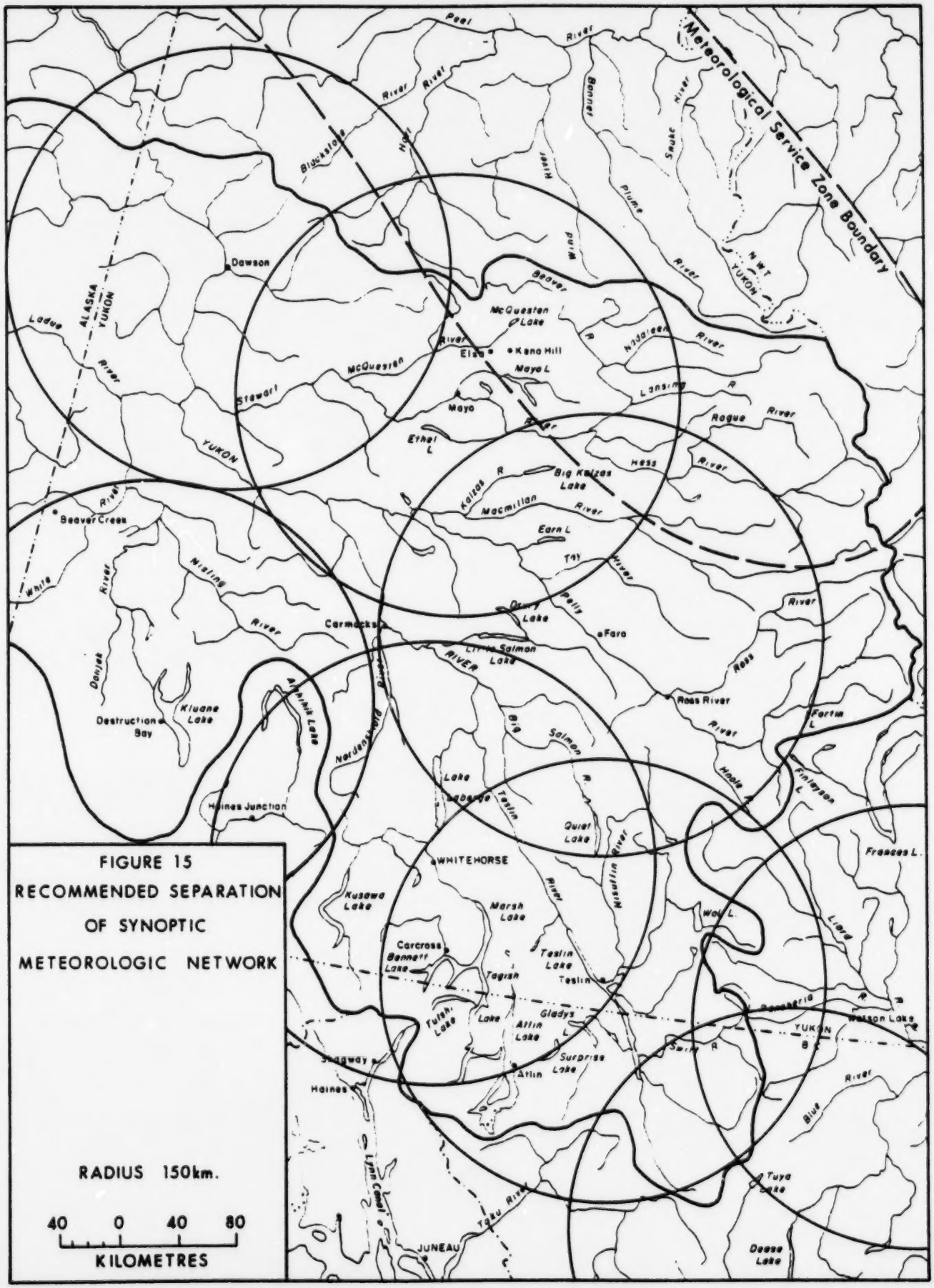

Meteorological Service Zone Boundary
Peel River
Bonnet Plume River
Snake River
Blackstone River
Dawson
ALASKA YUKON
Ladue River
Stewart River
YUKON
Beaver River
McQuesten River
McQuesten Lake
Elsa
Keno Hill
Mayo L
Mayo
Ethel L
Wind River
Hess River
Rogue River
Big Kalzas Lake
Kalzas R
Macmillan River
Earn L
Tay River
Beaver Creek
White River
Nisling River
Carmacks
Dezadeash River
Little Salmon Lake
RIVER
Fort Selkirk
Pelly River
Ross River
Destruction Bay
Kluane Lake
Aishihik Lake
Haines Junction
Big Salmon River
Lake Laberge
Teslin River
Quiet Lake
WHITEHORSE
Kusawa Lake
Marsh Lake
Carcross
Bennett Lake
Tagish
Teslin Lake
Teslin
Tutshi Lake
Atlin Lake
Gladys L
Surprise Lake
Atlin
Skagway
Haines
Lynn Canal
Taku River
JUNEAU
Finlayson L
Frances L
Wolf L
Lewes River
Dawson
Yukon R
Blue River
Tuya Lake
Dease Lake
FIGURE 15
RECOMMENDED SEPARATION
OF SYNOPTIC
METEOROLOGIC NETWORK
RADIUS 150km.
40 0 40 80
KILOMETRES

TABLE 22 ACTIVE SYNOPTIC METEOROLOGICAL NETWORK

STATION NUMBER	STATION NAME	TERRITORY PROV./STATE	LATITUDE (Degrees)	LONGITUDE (Degrees)	ELEVATION (Meters)	STATION ESTABLISHED
2100182	Burwash Airport	Y.T.	61 22	139 03	799	1966
2100402	Dawson Airport	Y.T.	64 03	139 08	369	1976
2100402	Komakuk Beach	Y.T.	69 35	140 11	14	1973
2100700	Mayo Airport	Y.T.	63 37	135 52	504	1969
2100517	Faro Airport	Y.T.	62 13	133 22	717	1974
2100950	Shingle Point	Y.T.	68 57	137 13	55	1973
2101100	Teslin Airport	Y.T.	60 10	132 45	705	1943
2101200	Watson Lake Airport	Y.T.	60 07	128 49	689	1938
2101300	Whitehorse Airport	Y.T.	60 43	135 04	703	1942
71958	Dease Lake	B.C.	58 25	130 00	816	1944

Yukon River basin most synoptic stations also provide hourly information. According to the recommended guidelines these stations should have a minimum radius of influence of 25 to 75 kilometers in Zone 1, less than 100 kilometers in Zone 2, and less than 250 kilometers in Zone 3 (Atmospheric Environment Service, 1983). The hourly meteorological network is listed in Table 23 and their locations are noted in Figure 16.

3.113 Upper Air Meteorological Network

The upper air network provides information at a synoptic scale primarily for aviation forecasting. This network monitors wind speed and direction, temperature and humidity at various levels of the lower atmosphere and often provides the only source of ground level temperature estimates for high elevation mountain areas. The recommended radius of influence for the upper air network is 250 kilometers in Zones 1 and 2, and 500 kilometers in Zone 3 (Environment Canada, 1979). Though only one meteorological station provided upper air information within the Yukon River basin, several surrounding stations are within the radius of influence. These are listed in Table 24 and their locations are shown in Figure 17.

3.12 Climate Station Network

The climate station network generally provides information which is used to define the climate of an area and to monitor and predict future variations in climate at either a regional or local scale. Within the climatological network are the ordinary climate station and supplementary climate station component networks.

3.121 Ordinary Climatological Network

Information recorded and reported by stations within the ordinary climatological network include at least daily temperature and precipitation, but generally the recording frequency is at least twice daily. In most cases reporting is less frequent than other component networks, often taking place monthly by mail to the regional AES headquarters where it is then archived. Some ordinary climatological stations also monitor parameters of a specialized nature to meet specific needs. Many of these stations are operated by outside agencies which have certain climatic requirements for operational needs within their own organizations. The majority of these cooperative stations are operated by volunteer observers, though AES generally will provide, install and periodically inspect the installation. Data

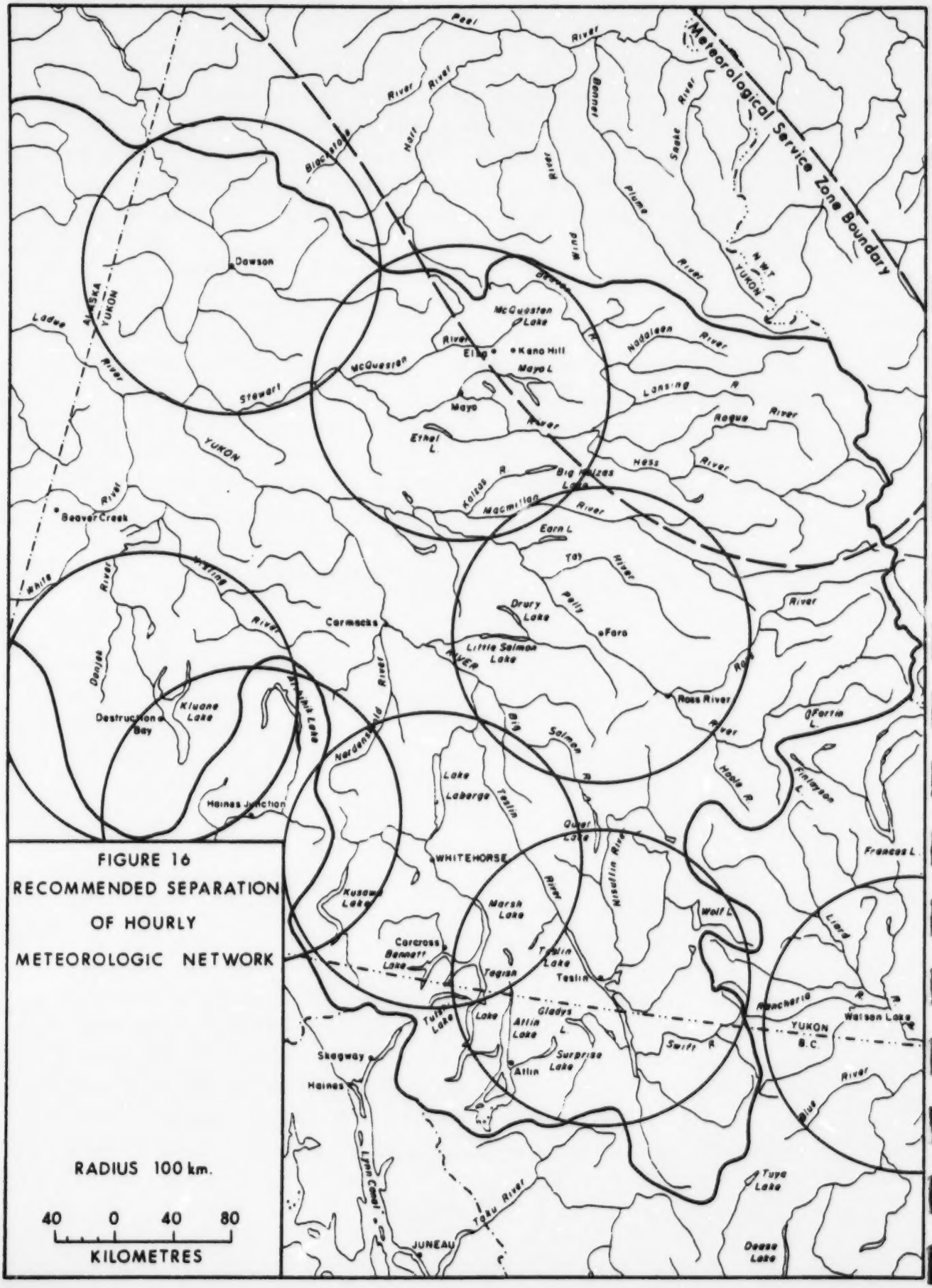


FIGURE 16
RECOMMENDED SEPARATION
OF HOURLY
METEOROLOGIC NETWORK

RADIUS 100 km.

40 0 40 80
KILOMETRES

TABLE 23 ACTIVE HOURLY METEOROLOGICAL NETWORK

STATION NUMBER	STATION NAME	TERRITORY (Prov.)	LATITUDE (Degrees)	LONGITUDE (Degrees)	ELEVATION (Meters)	STATION ESTABLISHED	CODE
2100182	Burwash Airport	Y.T.	61 22	139 03	799	1966	
2100402	Dawson Airport	Y.T.	64 03	139 08	369	1976	
2100518	Faro (Automatic)	Y.T.	62 14	133 21	717	1980	H
2100630	Haines Junction	Y.T.	60 46	137 35	599	1974	J
2100685	Komakuk Beach	Y.T.	69 35	140 11	14	1973	B
2100700	Mayo Airport	Y.T.	63 37	135 52	504	1924	
2100800	Old Crow	Y.T.	67 35	139 50	253	1975	
2100950	Shingle Point	Y.T.	68 57	137 13	55	1973	C
2101100	Teslin Airport	Y.T.	60 10	132 45	705	1943	D
2101102	Teslin (Automatic)	Y.T.	60 10	132 45	712	1976	H
2101200	Watson Lake Airport	Y.T.	60 07	128 49	689	1938	
2101300	Whitehorse Airport	Y.T.	60 43	135 04	703	1940	

Code Reference:

H - Meteorological Automatic Reporting Station - 24 hours a day

J - Irregular Observations - not processed

B - Eight (8) Observations per day

C - Four (4) Observations per day

D - Irregular Observations - daily

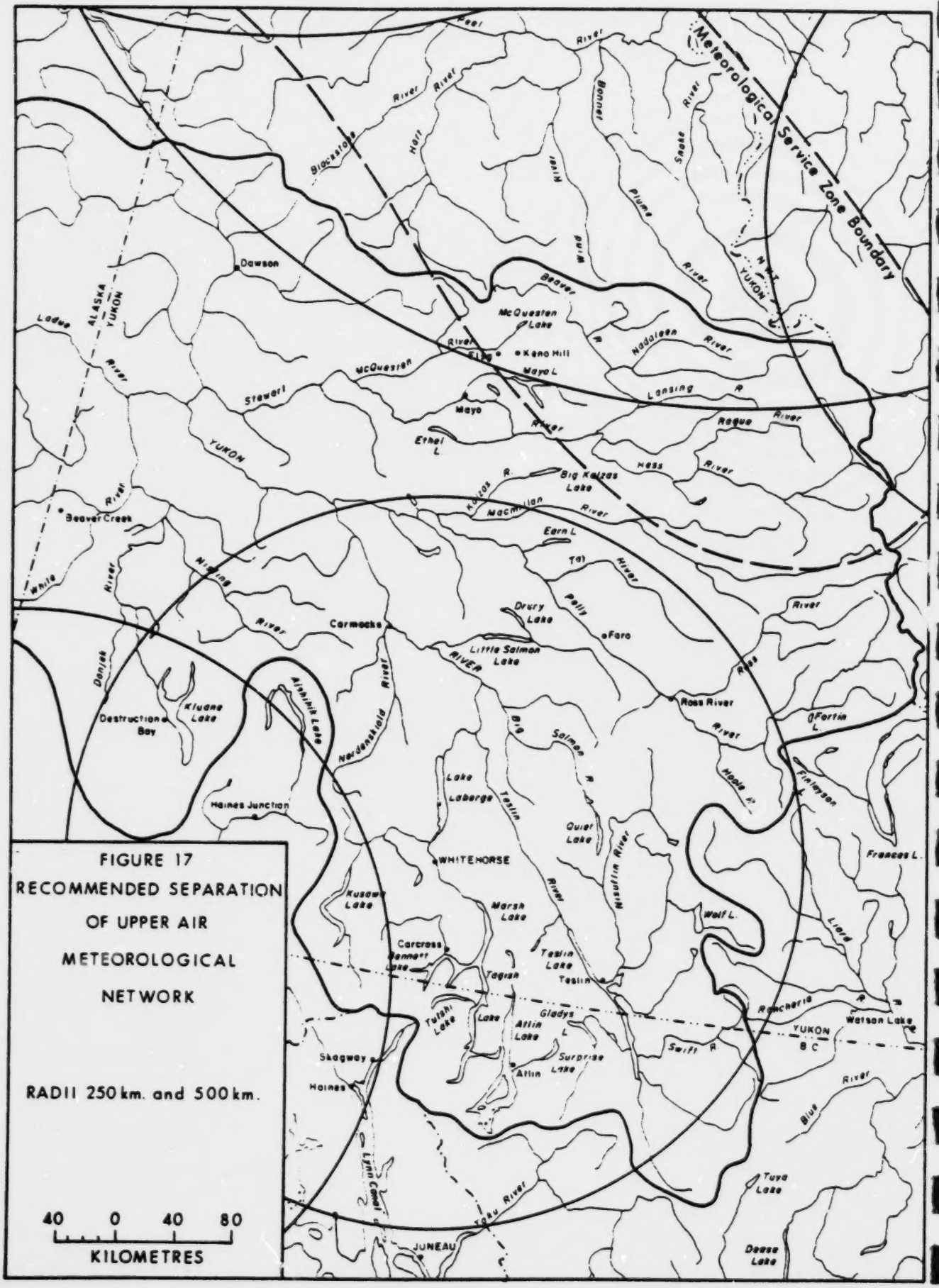


FIGURE 17
RECOMMENDED SEPARATION
OF UPPER AIR
METEOROLOGICAL
NETWORK

RADII 250 km. and 500 km.

TABLE 24 ACTIVE UPPER AIR METEOROLOGICAL NETWORK

STATION NUMBER	STATION NAME	TERRITORY PROV./STATE	LATITUDE (Degrees)	LONGITUDE (Degrees)	ELEVATION (Meters)	STATION ESTABLISHED
2101300	Whitehorse	Y.T.	60 43	135 04	703	1946
70086	Barter Island	AK	70 08	143 34	1.5	1947
2202570	Inuvik	N.W.T.	68 18	133 29	68	1960
2202800	Norman Wells	N.W.T.	65 17	126 48	73	1945
71945	Fort Nelson	B.C.	58 50	122 35	375	1942
70361	Yakutat	AK	59 30	139 36	10	1948
70261	Fairbanks	AK	54 49	147 51	132	1948

from these networks is inspected for quality and the records archived by AES. Long term stations with a minimum ten years record making up the ordinary climate network are listed in Table 25 and their locations are noted in Figure 18. Minimum radius of influence between stations comprising the ordinary climatological network (temperature and precipitation) according to the basic AES standards is twenty kilometers (Atmospheric Environment Service, 1975). Maximum separation should not exceed 150 kilometers (radius of influence 75 kilometers) (Figure 19). For illustration purposes a 50 kilometer radius of influence was used (Figure 20). This reduces the clutter presented by the 75 kilometer radius while indicating the major data gaps.

3.122 Supplementary Climatological Networks

Supplementary climatological networks include all remaining specific purpose networks. Generally these observe single parameters such as rate of rainfall or evaporation, though certain synoptic and hourly stations also provide this type of information. Agencies with particular needs which cannot be accommodated by existing AES stations often operate this type of network. AES and DIAND both operate precipitation networks which represent the main components of this category. These consist of long term recording and storage precipitation guages which are generally placed in remote locations where observer stations are impractical. Sparse data regions such as much of the Yukon River basin contain large unpopulated areas which are characterized by unique runoff producing areas. Information for design and flow forecasting purposes can be obtained by means of either a recording or storage gauge. Information from these networks is archived and published by AES. Stations making up these precipitation networks are listed in Table 26 and their locations are noted in Figure 21. Recommended separation between precipitation stations is less than for temperature because of a greater spatial variability. For relatively flat areas a value of 75 kilometers is cited as being appropriate; however, for areas where relief exceeds 250 meters for a significant portion of the area this value is reduced to 25 kilometers (radius of influence 12.5 kilometers) (Atmospheric Environment Service, 1975). Similar to temperature, the maximum acceptable separation is 150 kilometers. For illustration purposes these have been presented in Figure 22 with a radius of 50 kilometers.

For fire protection purposes forestry lookout towers within the territory have been instrumented to monitor temperature, precipitation, wind and cloud cover. Though the instruments are owned by DIAND they were installed and are

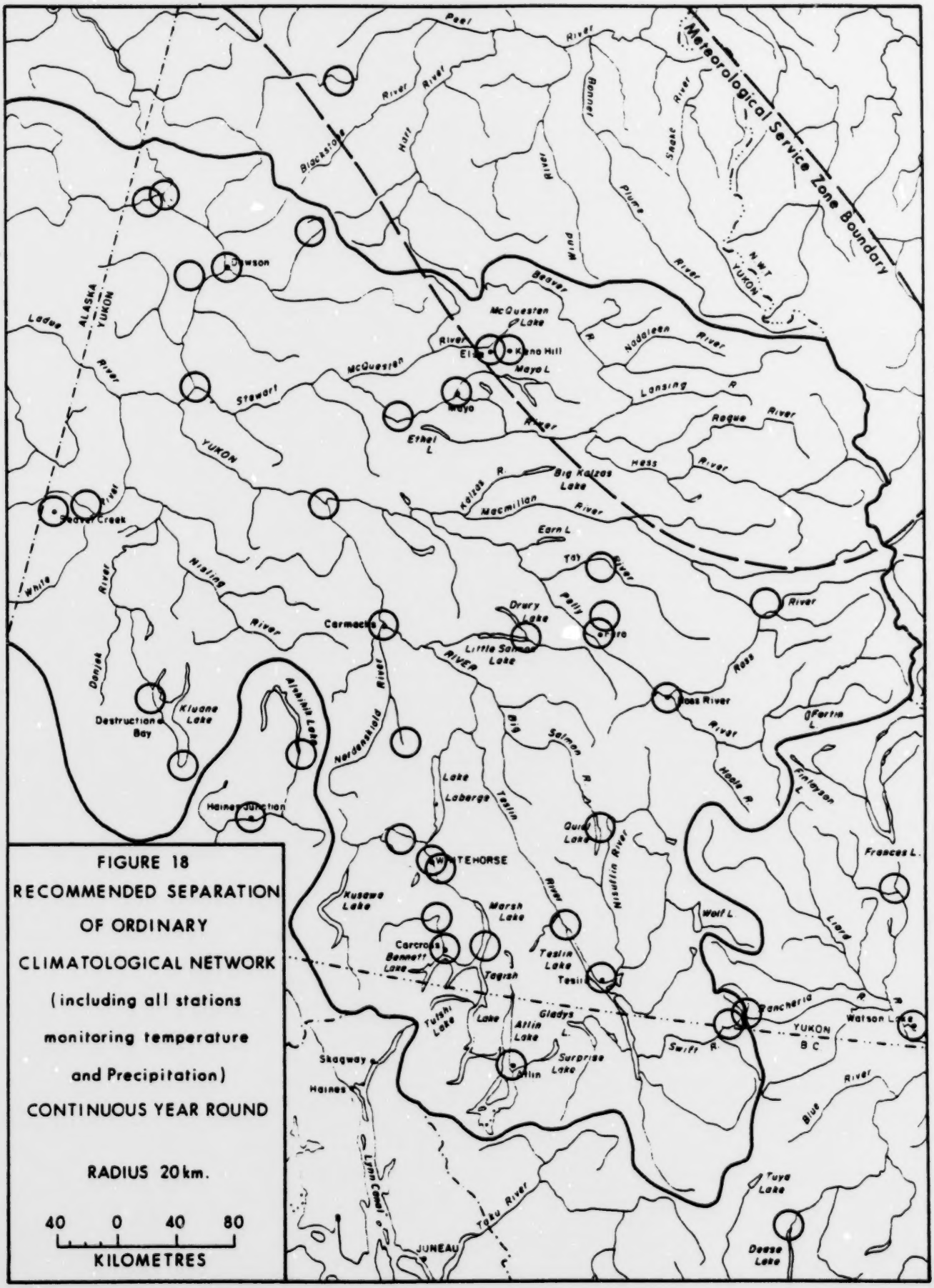


FIGURE 18

RECOMMENDED SEPARATION OF ORDINARY CLIMATOLOGICAL NETWORK

(including all stations monitoring temperature and Precipitation)

CONTINUOUS YEAR ROUND

RADIUS 20 km.

40 0 40 80

KILOMETRES

TABLE 25 EXISTING AND LONG TERM HISTORICAL ORDINARY CLIMATOLOGICAL NETWORK

STATION NUMBER	STATION NAME	TERRITORY (PROV.)	LATITUDE (Degrees)	LONGITUDE (Degrees)	ELEVATION (Meters)	STATION ESTABLISHED	STATION CLOSED
2100100	Aishihik Air Strip	YT	61 39	137 29	966	1943	1966
2100115	Annie Lake Road	YT	60 24	134 55	777	1976	
2100120	Anvil	YT	62 22	133 23	1158	1967	
2100160	Beaver Creek	YT	62 23	140 53	663	1968	1978
2100167	Braeburn	YT	61 28	135 47	716	1974	
2100200	Carcross	YT	60 10	134 42	663	1907	1979
2100300	Carmacks	YT	62 06	136 18	523	1950	
2100366	Clinton Creek	YT	64 28	140 44	576	1966	1978
2100400	Dawson City	YT	64 03	139 26	324	1897	1979
2100410	Dempster	YT	64 27	138 13	960	1966	1976
2100460	Drury Creek	YT	62 12	134 23	609	1970	
2100468	Eagle Plains	YT	66 15	137 00	720	1970	
2100500	Elsa	YT	63 55	135 29	844	1948	
2100600	Fort Selkirk	YT	62 49	137 22	454	1898	
2100605	Fortymile	YT	64 26	140 33	335	1978	
2100630	Haines Junction	YT	60 46	137 35	599	1958	
2100635	Herschel Island	YT	69 30	139 15	5	1896	1918
2100670	Johnson's Crossing	YT	60 29	133 18	690	1963	
2100677	Keno Hill	YT	63 56	135 12	1472	1974	
2100680	Kluane Lake	YT	61 01	138 24	786	1970	
2100794	Ogilvie River	YT	65 22	138 18	579	1971	
2100800	Old Crow	YT	67 35	139 50	253	1951	
2100840	Otter Falls	YT	61 02	137 02	830	1980	
2100900	Pine Lake	YT	60 46	137 35	597	1944	1958
2100910	Quiet Lake	YT	61 09	133 04	812	1966	
2100935	Rock River	YT	66 47	136 20	610	1974	
2100940	Ross River	YT	61 59	132 27	689	1967	
2100948	Sheldon Lake	YT	62 37	131 17	884	1970	
2101000	Snag Airstrip	YT	62 22	140 24	587	1943	
2101030	Stewart Crossing	YT	63 23	136 41	480	1980	
2101033	Stewart River	YT	63 19	139 26	358	1976	
2101070	Swede Creek	YT	64 06	136 45	320	1918	1929
2101081	Swift River	YT	60 00	131 11	891	1966	
2101089	Tagish	YT	60 18	134 16	658	1979	
2101095	Takhini River Branch	YT	60 52	135 32	756	1980	
2101099	Teslin	YT	60 10	132 45	705	1980	
2101135	Tuchitua	YT	60 56	129 15	724	1971	
2101138	Two Pete Creek	YT	62 38	133 42	960	1979	
2101300	Whitehorse	YT	60 43	135 03	636	1904	1942
2101400	Whitehorse Riverdale	YT	60 43	135 01	643	1959	
1200560-130	Atlin	BC	59 34	133 42	2210	1968	

TABLE 26 SUPPLEMENTARY CLIMATOLOGICAL NETWORK

STATION NUMBER	STATION NAME	TERRITORY/ PROV.	LATITUDE (Degrees)	LONGITUDE (Degrees)	ELEVATION (Meters)	STATION ESTABLISHED	TYPE	AGENCY
2100140	Babbage River	YT	68 52	138 38	299	1977	F/P	DIAND
2100162	Beaver River	YT	60 08	124 53	495	1977	F/P	DIAND
2200620	Cantung	NWT	62 01	128 23	1585	1973	F/P	AES
2100411	Dempster Mile 164	YT	65 47	137 47	854	1977	F/P	DIAND
2100612	Frances River	YT	60 29	129 08	754	1973	F/P	AES
2100612	Hyland River Strip	YT	61 30	128 16	854	1973	F/P	AES
2100696	Mactung	YT	63 17	130 11	1890	1972	F/P	AES
2100745	Montana Mountain	YT	60 04	134 38	1738	1978	F/P	DIAND
2100935	Rock River	YT	62 47	136 20	610	1974	F/P	AES
2100948	Sheldon Lake	YT	62 37	131 34	474	1976	F/P	DIAND
2101165	Wahl's Revenge	YT	63 23	131 34	474	1976	F/P	DIAND
2100430	Dezadeash	YT	60 22	137 03	725	1974	F/P	AES
2100947	Sheep Creek Upper	YT	61 01	138 37	1585	1975	F/P	AES
	Meadow Creek	YT	60 35	133 05	1235	1981	F/P	AES
2100302	Carmacks Tower	YT	62 11	136 29	1234	1974	SAC	AES
2100405	Dawson Tower	YT	62 04	139 20	1067	1974	SAC	AES
	Dempster Mile 48	YT	64 32	138 14	1235	1969	SAC	AES
	Finlayson	YT	61 38	130 32	1068	1972	SAC	AES
	Firth River	YT	69 25	139 30	27	1973	SAC	AES
2100690	Little Gold Creek	YT	64 05	141 00	1258	1974	SAC	AES
	Macmillan Pass	YT	63 14	130 02	1341	1972	SAC	AES
	Mt. McIntyre	YT	60 38	135 09	1585	1976	SAC	AES
2100850	Paint Mountain Tower	YT	60 50	137 30	1387	1976	SAC	AES
2100910	Quiet Lake	YT	61 09	133 04	813	1966	SAC	AES
2100960	Simpson Tower	YT	61 24	129 28	1677	1976	SAC	AES
2101031	Stewart Crossing Tower	YT	63 25	136 41	1250	1976	SAC	AES
2101093	Tagish Tower	YT	60 16	134 11	1220	1976	SAC	AES
2101125	Tom Creek Tower	YT	60 17	128 59	945	1974	SAC	AES
2101130	Transport tower	YT	60 10	130 00	1433	1974	SAC	AES
	Sekulman Lake	YT	61 34	137 32	915	1980	SAC	DIAND
	Tintina Strip	YT	61 06	131 15	1001	1980	SAC	DIAND
	Upper Frederick	YT	60 23	136 51	1250		SAC	AES
	Sheep Creek Lower	YT	61 00	138 37	1225	1974	SAC	AES
	Fraser	BC	59 43	135 03	869	1980	SAC	AES
2100310	Cassino Creek	YT	62 45	138 48	1065	1969	SAC	AES
2100677	Keno Hill	YT	63 56	135 12	1473	1974	SAC	DIAND
	McConnell/Rose	YT	61 29	132 50	1770	1982	SAC	DIAND
	Yukon Barite	YT	62 58	130 33	1446	1982	SAC	AES
	Tyers Pass Creek	YT	61 22	128 22	1631	1982	SAC	DIAND
	Lowell Glacier	YT	60 15	138 38	1372	1977	SAC	AES
2203922	Tungsten	YT	62 01	128 23	1588	1966	SAC	AES

Type: F/P - Fisher-Porter Continuous Recording Storage Gauge
SAC - Sacramento Storage Gauge

Agency: AES - Atmosphere Environment Service
DIAND - Department of Indian Affairs and Northern Development

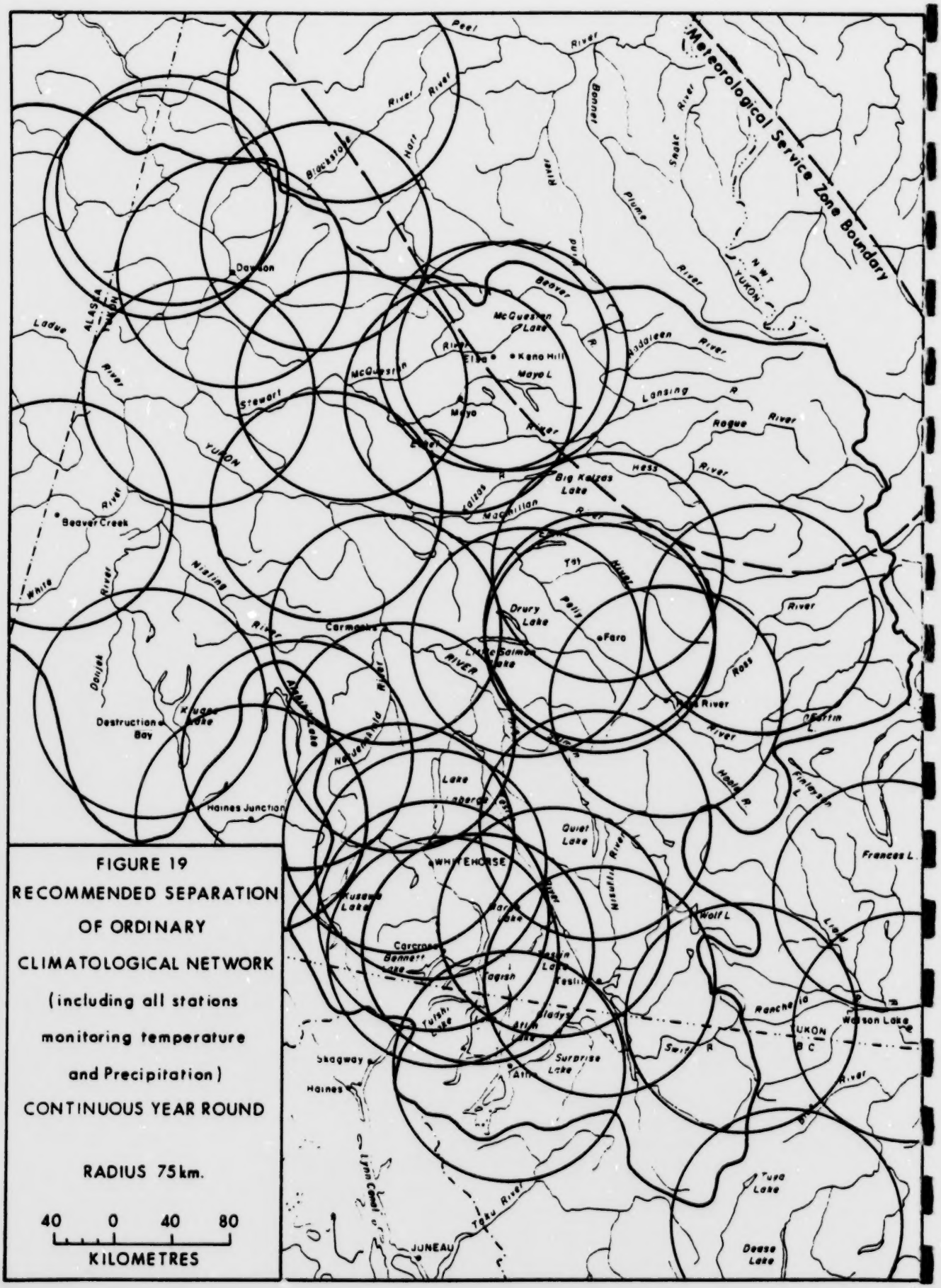


FIGURE 19

RECOMMENDED SEPARATION OF ORDINARY CLIMATOLOGICAL NETWORK

(including all stations monitoring temperature and Precipitation)

CONTINUOUS YEAR ROUND

RADIUS 75km.

40 0 40 80

KILOMETRES

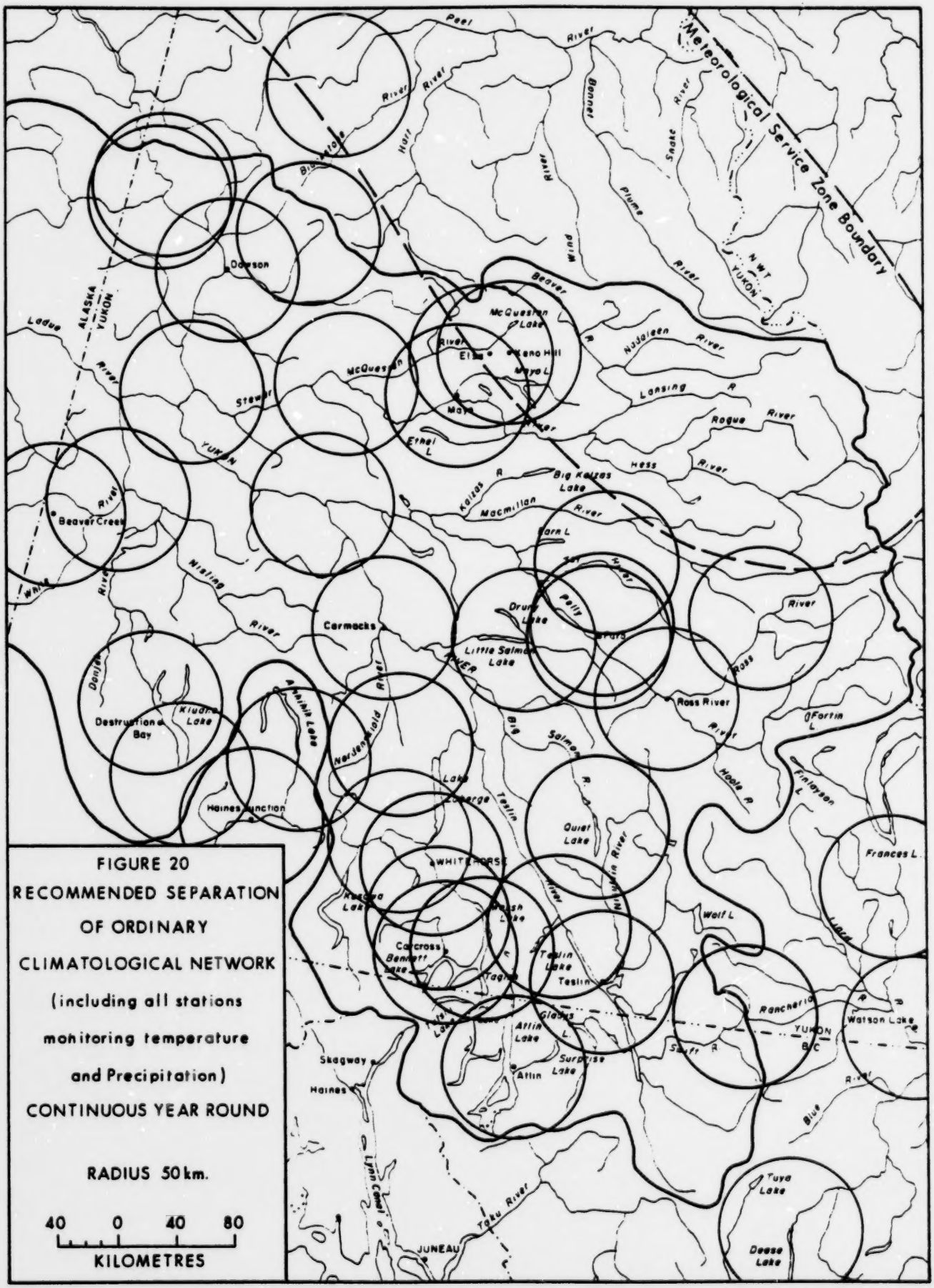


FIGURE 20
RECOMMENDED SEPARATION OF ORDINARY CLIMATOLOGICAL NETWORK
(including all stations monitoring temperature and Precipitation)
CONTINUOUS YEAR ROUND

RADIUS 50 km.

40 0 40 80
KILOMETRES

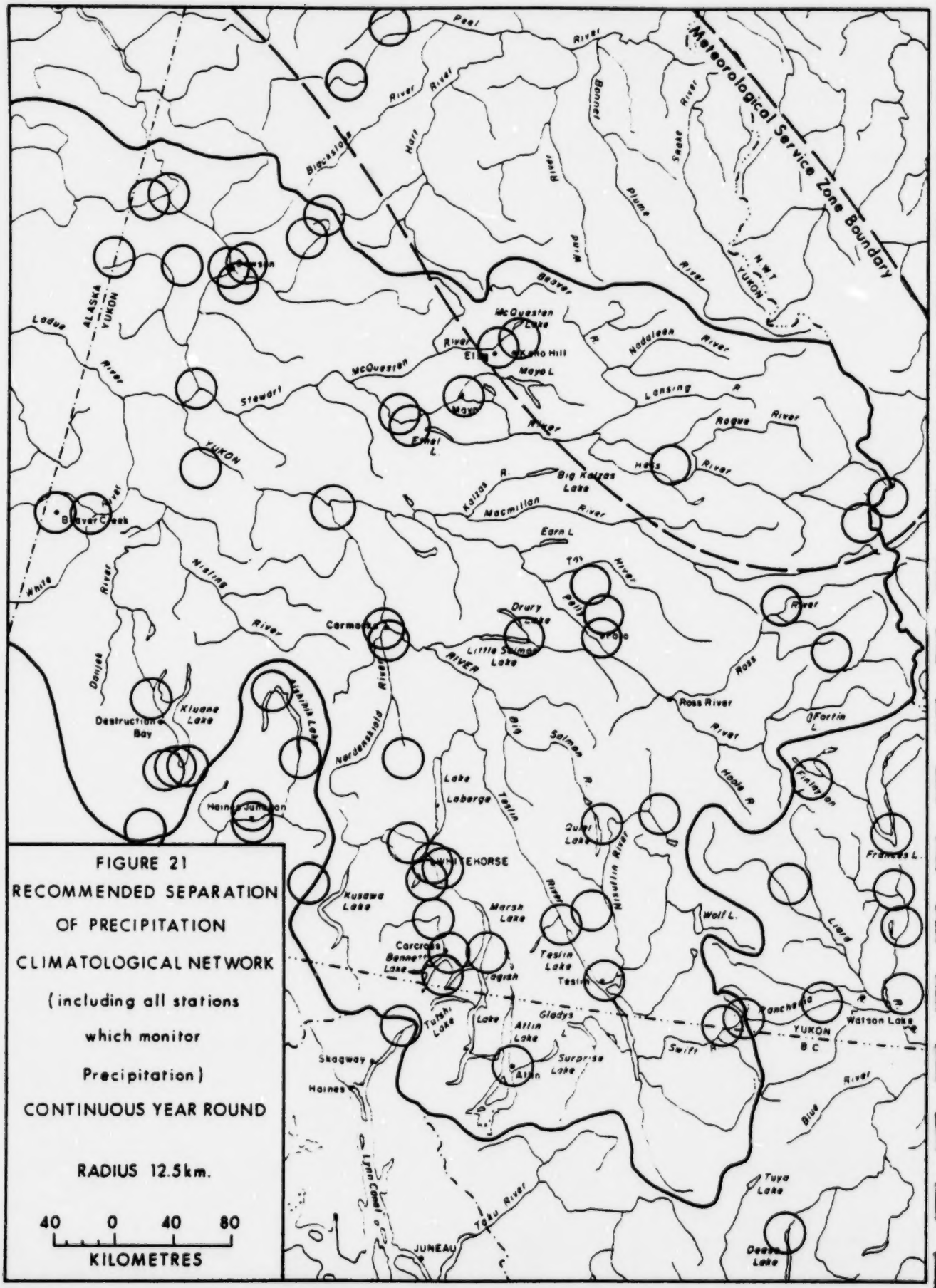


FIGURE 21
RECOMMENDED SEPARATION
OF PRECIPITATION
CLIMATOLOGICAL NETWORK
(including all stations
which monitor
Precipitation)
CONTINUOUS YEAR ROUND

RADIUS 12.5km.

40 0 40 80
KILOMETRES

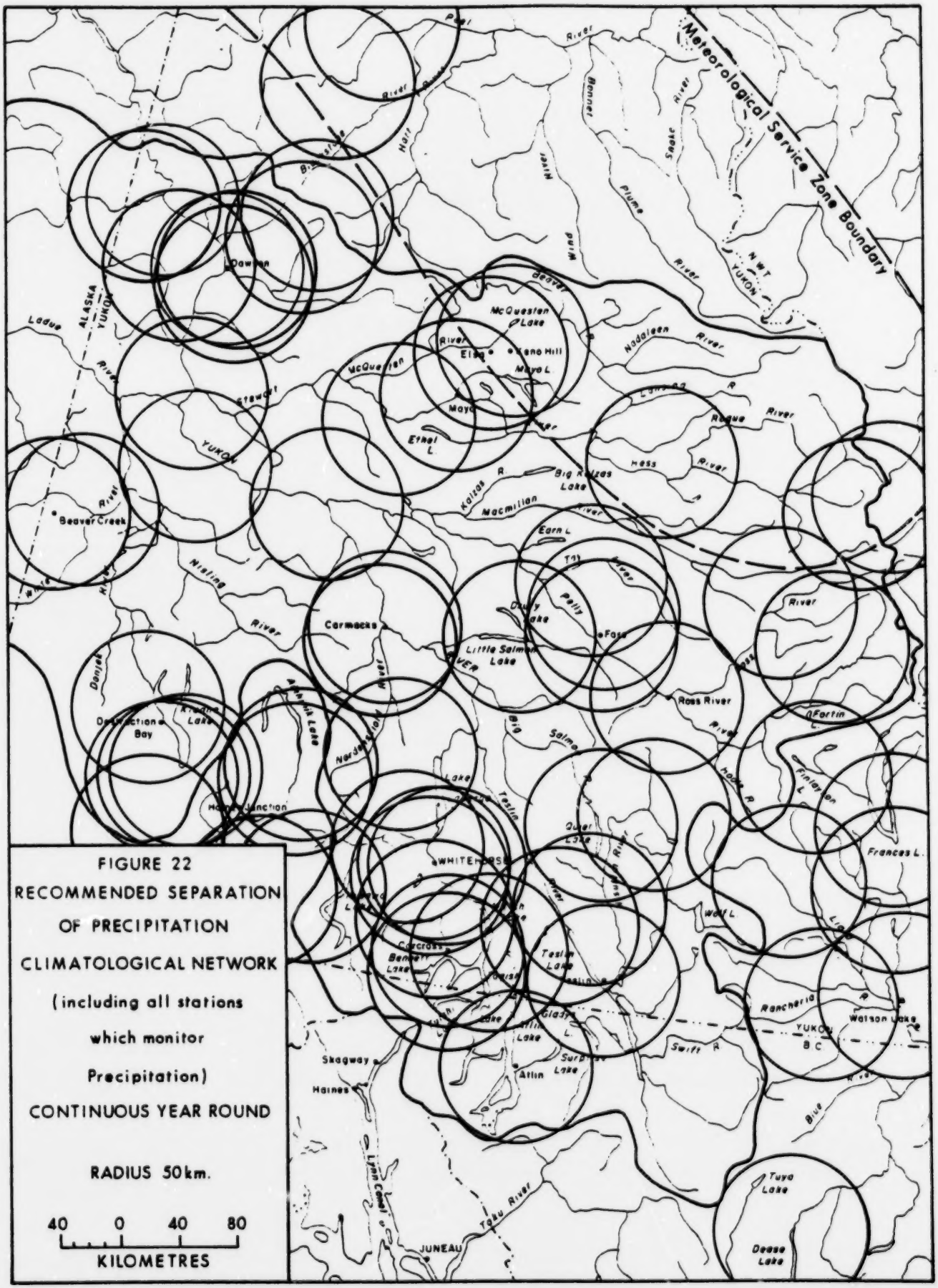


FIGURE 22
RECOMMENDED SEPARATION
OF PRECIPITATION
CLIMATOLOGICAL NETWORK
(including all stations
which monitor
Precipitation)
CONTINUOUS YEAR ROUND

RADIUS 50km.

40 0 40 80
KILOMETRES

periodically inspected by AES to ensure that the provided information meets national standards. These stations are manned during the summer only; however, long term storage precipitation gauges extend the utility to an annual basis. These stations are listed in Table 27 and their locations noted in Figure 23.

Point rainfall information is valid only for the immediate area surrounding the gauge. More often it is the case that a desired estimate is required for areas outside this radius of influence. In this case it is necessary to transfer the design information to ungauged areas using regional techniques. Areal coverage should be adequate to permit the derivation of rainfall intensity maps for the entire basin at various return periods and durations.

For the general evaluation of the water resources of an area a storage gauge network with manual observations is sufficient. Areal coverage should provide information on spatial variations while temporal variations could be determined from relatively long term stations. This data can also be used to provide daily rainfall amount and duration information at various recurrance intervals for accumulation periods of one to ten days. Estimates of the probable maximum precipitation can also be derived from this data.

Recording precipitation gauges provide the basis for rainfall intensity-duration frequency statistics which can be then translated to runoff probability using a selected hydrologic technique. These statistics can be provided for rainfall durations of five minutes to 24 hours. Table 28 lists the active and long term historical recording precipitation stations, and their locations are noted in Figure 24.

3.2 Assessment of Meteorological and Climatological Networks

No previous rigorous network assessment or planning exercise has been carried out for Yukon Territory as a whole, though portions of the Territory were included in the recent network assessment completed for the MacKenzie River basin.

Johnstone (1983) carried out a statistical assessment of the climatological network of the MacKenzie River Basin using monthly precipitation and temperature. The objective of that study was to assess the ability of the network to interpolate monthly information at a point without differentiation between network types. The standard error of estimate was related to the area over which each station was considered to be representative. The results of the temperature

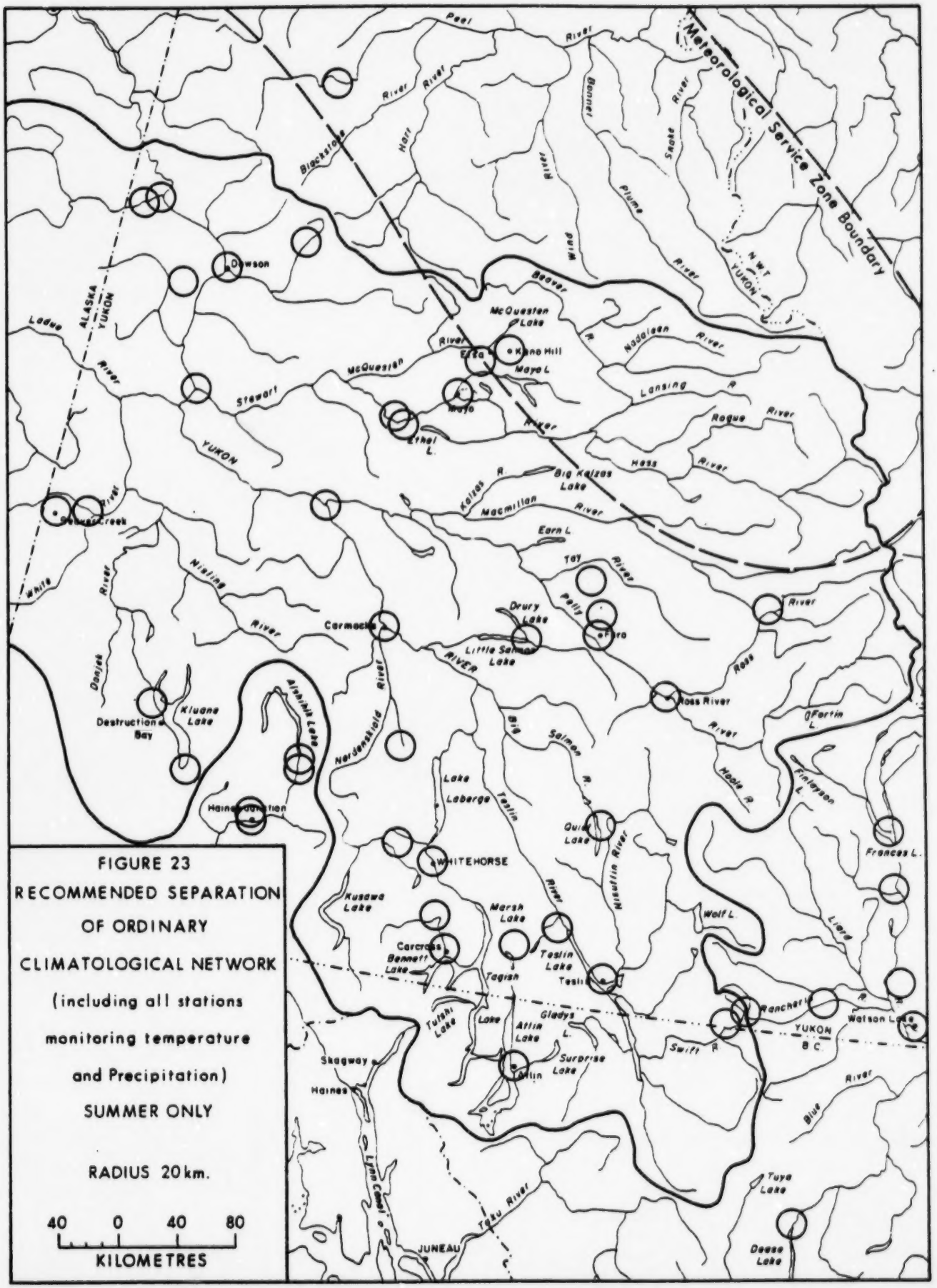


FIGURE 23
RECOMMENDED SEPARATION OF ORDINARY CLIMATOLOGICAL NETWORK
(including all stations monitoring temperature and Precipitation)
SUMMER ONLY

RADIUS 20 km.

40 0 40 80
KILOMETRES

TABLE 27 FORESTRY CLIMATOLOGICAL STATIONS

STATION NUMBER	STATION NAME	TERRITORY PROV./STATE	LATITUDE (Degrees)	LONGITUDE (Degrees)	ELEVATION (Meters)	STATION ESTABLISHED
2100302	Carmacks Tower	Y.T.	62 11	136 29	1,234	1974
2100405	Dawson Tower	Y.T.	64 04	139 20	1,067	1974
2100620	Haeckel Hill Tower	Y.T.	60 45	135 13	1,433	1974
2100850	Paint Mountain Tower	Y.T.	65 17	126 48	73	1945
2100960	Simpson Tower	Y.T.	61 24	129 28	1,676	1976
2101031	Stewart Crossing Tower	Y.T.	63 25	136 41	1,250	1976
2101093	Tagish Tower	Y.T.	60 16	134 11	1,219	1976
2101125	Tom Creek Tower	Y.T.	60 17	128 59	945	1974
2101130	Transport Tower	Y.T.	60 10	130 00	1,433	1974

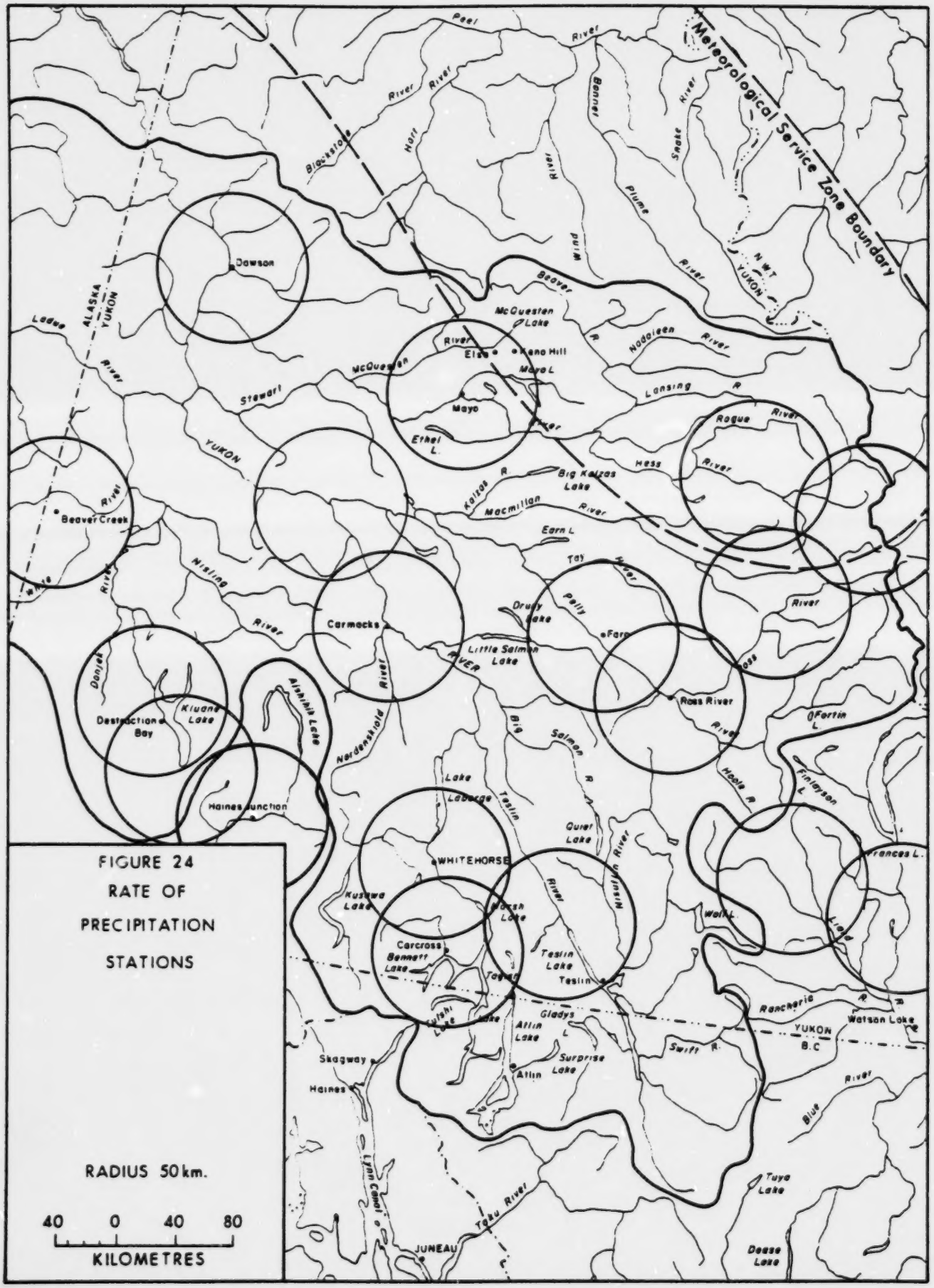
TABLE 28 RATE OF RAINFALL - ACTIVE AND LONG TERM HISTORICAL STATIONS

STATION NUMBER	STATION NAME	TERRITORY (PROV.)	LATITUDE (Degrees)	LONGITUDE (Degrees)	ELEVATION (Meters)	STATION ESTABLISHED	STATION CLOSED	TYPE
2100140	Babbage River	YT	68 52	138 38	299	1977		S
2100162	Beaver River	YT	60 08	124 53	518	1977		S
2100160	Beaver Creek	YT	62 23	140 53	663	1968	1978	X
2100182	Burwash A.	YT	61 22	139 03	799	1966		X
2100300	Carmacks	YT	62 06	136 18	523	1963		X
2100402	Dawson A.	YT	64 03	139 08	369	1976		X
2100411	Dempster 164	YT	65 47	137 47	853	1977		S
2100600	Fort Selkirk	YT	62 49	137 22	454	1975		X
2100612	Frances River	YT	60 35	129 11	732	1973		S
2100630	Haines Junction	YT	60 46	137 35	599	1964		X
2100640	Hyland River Strip	YT	61 30	128 16	853	1973		S
2100696	Mactung	YT	63 17	130 11	1890	1972		S
2100700	Mayo A.	YT	63 37	135 52	504	1975		X
2100745	Montana Mountain	YT	60 05	134 40	1752	1978		S
2100760	Mush Lake Upper	YT	60 08	137 26	1676	1977		S
2100935	Rock River	YT	66 47	136 20	610	1974		S
2100947	Sheep Creek Upper	YT	61 01	138 37	1585	1975		S
2101165	Wahl's Revenge	YT	63 23	131 34	1554	1976		S
2101300	Whitehorse A.	YT	60 43	135 04	703	1959		X
2203922	Tungsten	NWT	61 57	128 15	1143	1975		X
210110	Teslin A.	YT	60 10	132 45	705	1967		X
2101200	Watson Lake A.	YT	60 07	128 49	689	1969		X

Explanation of Types

X - Tipping Bucket Recording Rain Gauge

S - Fisher/Porter Recording Gauge


Meteorological Service Zone Boundary
Peel River
Bonnet Plume River
Snake River
Blackstone River
Hart River
Wind River
Beaver River
ALASKA YUKON
N.W.T. YUKON
Dawson
Ladue River
McQuesten Lake
Elsa
Keno Hill
Mayo L.
Mayo
McQuesten River
Nadaleen River
Lansing R.
Stewart River
Ethel L.
YUKON
Rogue River
Hess River
Big Kalzas Lake
Kalzas R.
Macmillan River
Beaver Creek
White River
Earn L.
Tay River
Pelly River
Drury Lake
Carmacks
Little Salmon Lake
Nisling River
Dezadeash River
Destruction Bay
Kluane Lake
Aishihik Lake
Nordenskiold River
Haines Junction
Ross River
Fortin L.
Big Salmon R.
Hoole R.
Finlayson L.
Lake Laberge
Teslin River
Quiet Lake
WHITEHORSE
Kusawa Lake
Marsh Lake
Nisutlin River
Wolf L.
Frances L.
Carcross
Bennett Lake
Tagish
Teslin Lake
Teslin
Ranchería R.
Watson Lake
Gladys L.
Atlin Lake
YUKON
B.C.
Skagway
Atlin
Surprise Lake
Swift R.
Haines
Blue River
Lynn Canal
Tuya River
Tuya Lake
JUNEAU
Dease Lake
FIGURE 24
RATE OF
PRECIPITATION
STATIONS
RADIUS 50 km.
40 0 40 80
KILOMETRES

component of the study were poor; therefore emphasis was placed on the precipitation network. Thirty-five precipitation stations were recommended for addition to the Mackenzie River Basin network. It was suggested that without this additional information further statistical applications of data transfer techniques and network assessments would be severely limited.

Another AES report (Forbes and Kotylak, 1979) which dealt with the network design of the forest tower observation network in the MacKenzie Valley rejected a statistical approach due to the paucity of data in this region. Similarly, Meeres (1981) adopted a subject approach to the assessment of the meteorological network of the MacKenzie River Basin by comparing AES guidelines to the existing networks.

A recent study carried out by the Western Region of AES (Meeres, 1978) suggested that network design should be based on the topography of the area and the productivity, social needs and development potential of the area. It also suggested using short term stations to develop functional relationships between physiography and climatic parameters which are suitable for transfer to nearby areas.

Peck (1980) likewise emphasized the need to include the relationship between precipitation and physiographic parameters in designing and assessing climatological networks. The Scientific Services Division of AES (Atmospheric Environment Services, 1981) recommended a proposal for a meteorological network based on the existing synoptic network as benchmark stations since these are expected to remain active indefinitely. In addition to other parameters, this network would provide estimates of monthly annual precipitation and temperature. A maximum separation of 250 kilometers was proposed for the MacKenzie River basin, though it was suggested that supplementary stations be included in mountain areas.

An additional baseline network is recommended to provide temperature and precipitation data representative of regional characteristics of the median elevations of the area. Topography and climatic variability should be accounted for in determining station density; however, maximum separation of 150 kilometers is recommended for areas of low relief. Additional stations or supplemental precipitation stations may be required.

The various meteorological and climatological data networks discussed above have been assessed with respect to fulfilling both baseline and site specific requirements. These terms have been defined earlier. Generally baseline requirements refer to the particular network objectives as defined by AES for weather

forecasting and characterization purposes, and for water management purposes. Site specific requirements refer to the information which is needed for current use or potential developments.

Initially a statistical assessment was to be included in the overall evaluation. However, due to the extreme variability of climatic parameters this was thought to be inappropriate. Variations in these parameters are dependent in turn on the variability in weather systems and physiography. Though the long term passage of weather systems is generally fixed with respect to time and space, elevation as a third dimension greatly affects the variability of meteorological parameters. The majority of meteorological and climatological stations are located in the major valleys of the Yukon River basin. However, the elevation variation is such that meteorological characteristics, especially precipitation, are not comparable. With a sufficiently long and dense data base these variations become predictable. However, since the majority of the Yukon River basin represents a sparse data region this is not the case. Little specific information is available to define the variation of climatic variables with elevation. On this basis a statistical assessment was not attempted.

The technique used to assess the various networks with respect to baseline requirements is based on the spatial distribution of the stations. This approach was recommended by Schaeffer (1983) and is similar to that adopted by the Scientific Services Division of AES (Atmospheric Environment Service, 1981). The minimum criteria utilized are based on World Meteorological Organization guidelines, but have been modified by AES to meet Canadian needs. In some instances these have also been modified for study purposes. The WMO recommended density for precipitation stations in mountainous areas in temperate regions is one station for every 100 to 250 square kilometers. This is equivalent to a radius of influence of six and nine kilometers respectively. Under difficult conditions, such as remote areas with low population densities, a lack of development of communication facilities and other economic reasons, this range may be extended to 250 to 1,000 square kilometers for each station, or a radius of influence of nine and 18 square kilometers respectively (WMO, 1965). Under extremely difficult conditions these guidelines are extended to 2,000 square kilometers. These guidelines have been developed for precipitation stations, but are applicable to general climate stations.

For the purpose of this analysis only existing stations were considered in the assessment of the meteorological component networks whereas historical stations

with a minimum ten years of record were considered in the climatological component networks.

3.21 Meteorological Station Network Component

The meteorological networks may for the most part be adequate for weather prediction purposes, WMO requirements and for the definition of meteorological parameters at a broad scale.

The synoptic network generally provides adequate coverage of the Yukon River basin according to the criteria used by AES (150 kilometer radius of influence) as shown in Figure 15. As the figure illustrates, the only areas lacking coverage are portions of the Selwyn Mountains. This region is presently largely unpopulated with the exception of Tungsten, Northwest Territories. Though this may be a low priority a synoptic station located at Tungsten would fulfill the requirements of this network by providing additional coverage for the majority of the ungauged area. A station at Tischu River would fill the remaining gap.

The hourly meteorological network which is used primarily for reporting and forecasting weather for aviation purposes consists of the same stations as the synoptic network. However, since the recommended separation is less than the former network (100 kilometers recommended maximum) coverage is not complete by these standards as Figure 16 indicates. Two large gaps exist in the interior of the basin centered on the Yukon River and much of the Selwyn Mountains. The former gap could largely be filled with stations at Carmacks and Beaver Creek; however, since coverage is available north of this area this may be a low priority. The latter gap, however, represents the peripheral of an extensive area lacking information for weather forecasting purposes. As with the synoptic network, stations at Tungsten and Tischu River would provide coverage for the majority of the area.

The upper air network is represented by only one station in the Yukon River basin. Located at Whitehorse, it provides coverage for approximately half the basin with the recommended separation of 500 kilometers. Regions north of Beaver Creek and Pelly Crossing and east of Ross River lack coverage. The Norman Wells station provides information for the peripheral divide area of the Selwyn Mountains and Inuvik provides information for the Peel River basin and other areas to the north. Though probably not a high priority, this area has some international

aviation requirements. A station at Mayo would fill the gap, providing aviation information in addition to other uses.

3.22 Climatological Station Network - Baseline Requirements

Unlike the meteorological network which consists of primarily baseline stations, the climatological network is made up of both baseline and site specific stations. The techinique used to assess the baseline portion of the climatological network was, as the meteorological network, based on areal coverage with respect to station separation. The climatological network for baseline purposes, which is used to define the regional climate of the network, is less adequately gauged than the various meteorological networks. Ordinary climate stations (temperature and precipitation) according to AES guidelines should have a radius of influence of 20 kilometers with a maximum recommended radius of 75 kilometers. All stations which measure temperature and precipitation are included in this category for the purpose of this study. In addition, this has been separated into year round and summer only to accommodate the forestry stations which are active for both temperature and precipitation during the summer period only (precipitation year round using a storage precipitation gauge). The two networks are illustrated in Figures 18 and 23. Inspection of Figure 18 indicates that coverage of the basin at the optimal density is inadequate for the year round ordinary climatological network. Several large data gaps, primarily in remote areas, are evident. The St. Elias-Coastal Mountain regions are generally adequately gauged. Two major deficient areas have been identified in the Upper Yukon region. These are the Kusawa area and the upper Teslin-Yukon. Similarly, the mid-Nisling and lower Macmillan areas within the central Yukon region have been identified as deficient. The Pelly-Cassiar Mountains region has deficiencies in the upper Nistulin-Hoole (Liard Divide) and the mid-Teslin (Big Salmon) areas. The Ogilivie-Mackenzie Mountain regions similarly are deficient in the mid-Ross and Mid-Hess areas.

Inspection of Figure 19, which illustrates the maximum recommended spacing, provides a similar conclusion, though with considerable overlap in populated areas. For presentation purposes a radius of 50 kilometer was selected to indicate data gaps (Figure 20). Again the St. Elias-Coastal Mountain regions are adequately monitored while a large gap has been identified in the upper Teslin-Yukon area of the Upper Yukon region. Deficiencies are noted in the mid-Nisling and lower Macmillan areas of the central Yukon region, while the Pelly-Cassiar Mountains

region is generally adequately covered. The Ogilivie-Mackenzie region has the most extensive deficiencies with no existing stations and few historical records in the upper Hess, Ross and Pelly River areas.

Unfortunately, these areas for the most part are unpopulated, negating the establishment of manned observer stations. The most reasonable alternative to meet the desired objectives would be through an automatic reporting station such as a Mars II (Meteorological Automatic Reporting Station) or a more advanced satellite interogated system.

Little difference in regional coverage is achieved with the inclusion of the ten forestry lookout stations which are operated during the summer only (Figure 23). The majority of these stations are located on the highway network, which generally already has adequate coverage, although these do provide some higher elevation data.

The supplementary climatological network consists of all specific purpose networks which have not yet been considered. As discussed above, the main components of this category within the Yukon River basin are precipitation networks consisting of long term storage and recording precipitation gauges. The spacial distribution of these with respect to baseline needs is assessed here.

To define the climate of a given area both physically and statistically, and to monitor and predict the variation of climate due to both natural and unnatural causes, it is necessary to obtain a set of observational data over a relatively long period of time. The desired period interval is a function of the purpose, and the level of accuracy desired. A minimum of ten years is required for even basic statistical procedures. A record duration of thirty years is suggested as being more appropriate as a lower limit of acceptability (Peck, 1980).

For the evaluation of the baseline storage precipitation network all stations reporting precipitation parameters are included. Forestry tower stations are also included since these provide year round coverage for precipitation amounts. The locations of the stations comprising this network are noted in Figure 21. Station density of this network appears to be reasonable with respect to areal coverage. The St. Elias-Coastal Mountain regions are generally adequately covered, while relatively large data gaps are present in the upper Teslin area of Upper Yukon region. Similarly, deficiencies have been identified in the mid-Nisling and lower Macmillan areas of the Central Yukon region, and the mid-Tesline area of the Pelly-Cassiar Mountains region. In the previously considered networks the large gap present in the Selwyn Mountains has been for the most part filled by supplementary

precipitation stations, though a large gap is present in the extreme northeast peripheral of the basin. A maximum separation of 75 kilometers is recommended for precipitation networks; however, for illustration purposes Figure 22 presents the total precipitation network with a 50 kilometer radius of influence.

The recording precipitation network which monitors precipitation intensity is necessary to define the areal distribution of intensity-duration frequency statistics. A separation of 25 kilometers is recommended for this network with a maximum of 150 kilometers. For illustration purposes Figure 24 presents this network with a 50 kilometer radius of influence. Major gaps are present in the upper Teslin-Yukon area of upper Yukon region, the mid-Nisling, lower Stewart and lower Macmillan areas of the central Yukon region, the mid-Teslin area of the Pelly-Cassiar Mountains region and in the northeast boundary area of the basin in the Ogilivie-Mackenzie Mountains region.

3.23 Climatological Station Network - Site Specific Requirements

As discussed above, precipitation is the most significant variable with respect to water management and planning, with temperature and other parameters having secondary importance. Knowledge of the various aspects of the temporal and spatial distribution of precipitation is needed for site specific requirements. The design of the precipitation network should be compatible with the information use, and with the topography of the area concerned. Information provided by storage gauges is essential for the provision of water availability estimates for proposed or operating water management schemes such as hydroelectric developments, surface and placer mining operations, and water supply systems. For certain types of operations annual values of precipitation are sufficient, where others require monthly values or other frequency of observations. Recording precipitation stations are often required to form the basis for hydraulic design estimates. Certain hydrologic techniques rely on precipitation intensity-duration frequency information and translate these to runoff probabilities. The potential and existing data uses discussed above have been assessed for site specific requirements.

As discussed above, the most probable mining potential exists in the Macmillan Pass, Howards Pass, and the Venus property near Carcross. The former area is adequately represented with a storage and a recording precipitation gauge near Macmillan Pass.

No climatological information is available for Howards Pass, and since the area is presently in a remote setting an observer station is not feasible. A recording precipitation station would provide valuable information until such time that exploration activities permit the re-establishment of an observer station.

The Venus Mine near Carcross was at the production stage when declining mineral prices forced its closure. Since it currently is beyond the design stage no site specific information is required. A nearby recording rain guage may provide any additional information which may be needed.

The most promising potential hydroelectric developments should be adequately gauged to provide site specific information for design purposes. As discussed above, the intermediate to large scale projects are the mid-Yukon Project at Eagles Nest Bluff, Pelly (Hoole), Pelly (Granite) and Teslin. The smaller scale projects are Squanga Creek near Teslin and the two Atlin proposals.

The mid-Yukon project encompasses such a large drainage area that the existing climatological network probably provides the necessary site specific information, though at this scale streamflow information has a greater utility.

No hydrometeorological information is available for the upper Pelly basin, and the Ross River site is not representative of this upper elevation area. Since this represents a sparse data region a manned observer site is not feasible. A storage gauge would provide useful information for reservoir inflow estimates, however a recording precipitation gauge would also provide estimates of peak design flows.

The Nisutlin River basin, which represents approximately one half of the area providing input to the Teslin hydro project site, has adequate climatological monitoring. No information is available, however, for the headwater areas of the Teslin River itself. A remote precipitation station would provide useful information for water availability analyses.

Information provided by the Meadow Creek recording precipitation station near Johnsons Crossing is probably representative of the upper Squanga basin since both areas are on the western slopes of the Big Salmon Range. No additional climatological information is thought to be required.

No high elevation climatological information is available for the Atlin Lake headwaters. A remote storage or recording precipitation station would provide valuable inflow information for this area.

Site specific monitoring of climatological parameters for the North Klondike basin component of the Klondike power project is adequate. No site specific information is available for the main fork; however, since the project does not require reservoir storage and only uses a portion of summer high flows, a climatological station is probably not required.

Since the major proposed linear facilities are generally within or nearby the existing highway network right of ways, sufficient design information is currently available. Similarly, no potential recreation developments in the basin require climatological information.

Of the existing operational uses it has become evident that insufficient information is available to define inflows to the headwater lakes of the Yukon River basin. This information, which is currently estimated, is needed for reservoir management purposes for the Whitehorse Rapids plant. This data could ideally be provided by a precipitation and temperature station in the headwater area of Bennett Lake.

Both precipitation and temperature information would be useful for spring flood forecasting at Ross River and Mayo. The appropriate locations would be the median elevations of the Pelly and Stewart basins. For optimum use the information is required on a real time basis.

4.0 SNOW COURSE NETWORK

Snowmelt is the primary source of streamflow in many areas. This is especially true of northern and high elevation regions such as the Yukon River basin. It has been estimated that 60 to 70 percent of total precipitation is in the form of snowfall throughout much of the basin. For this reason it is important to understand the nature and distribution of snowfall and the mechanisms involved in the snowmelt process in order that adequate estimates of streamflow may be derived. There are many uses of snowpack information, including basin wide water availability estimates, reservoir inflow analyses, and flood forecasting. Other uses include snow road design, assessment of fire hazard potential, and wildlife migration studies. The adequate knowledge of the snowpack and the snowmelt process in a particular area makes it possible to predict and in some cases manipulate the corresponding runoff with respect to both magnitude and timing. Snowmelt runoff is usually out of phase with the periods of greatest water need, and as a result reservoirs are used to store the water for release during traditional low flow periods.

Snowfall may be measured using storage recording type precipitation gauges at locations where these instuments exist. At locations without precipitation gauges snowpack parameters are usually derived by direct measurement of the snowpack. A single point value is not usually very representative of a large area due to the variable distribution of the snowpack as a result of uneven accumulation and drifting.

To account for variable snowpack characteristics specialized snow sampling techniques have been developed which provide information on snow depth, snow water equivalent, and density. Samples are taken at a number of locations in a set pattern approximately 25 meters apart. Generally ten sampling locations make up a snowcourse. These locations are permanently marked so that samples may be taken at the same location during each survey. Due to the usual increase of precipitation with elevation it is desirable to locate a snow course at the median elevation of the basin of interest. To assess the long term variation in snowpack characteristics it is necessary to carry out snow surveys according to a consistent schedule on an annual basis. In western and northern North America snow surveys are carried out simultaneously by different agencies at the first of each month, starting during February. In Yukon Territory surveys are carried out February 1, March 1, April 1, May 1, May 15, and June 1 if necessary. Other agencies may

start earlier or sample later to suit their own purposes. From a hydrological point of view snow water equivalent is generally the most important parameter. This is obtained by weighing the sample and represents the depth of water that would weigh the same amount as that particular sample.

Due to logistical and cost limitations, attempts have been made to develop alternative methods of obtaining snowpack estimates. Snow courses are often located in isolated areas requiring much time and expense to sample. One alternate method relies on aerial snow markers. These consist of graduated stakes which can be read from the air. The obtained depth measurements are converted to snow water equivalent using a predetermined value for density. Generally measurements for accessible survey locations are used to provide a good index of snow density. This technique has had limited success in parts of the basin due to the shallow nature of the snowpack. Because measurement resolution is plus or minus .2 meters this has a considerable affect on the total snowpack.

A pressure pillow provides a means of obtaining a continuous record of the accumulating snowpack. This consists of an air bag which is filled with an anti-freeze solution and connected to a masometer which records the amount of overlying snow. This instrument has the ability to characterize snow depth, rate of snowfall, and rate of snowmelt. Unfortunately, it has proven to be not very satisfactory for shallow snowpacks.

More recently photographic techniques are proving to be valuable in assessing the extent and volume of snow cover. Standard black and white aerial photography can be used to adequately represent areal distribution of the snowpack, while colour and thermal infared, relying on different wave lengths, are capable of distinguishing between snow, ice, water and other features.

A more unusual method of determining the snow water equivalent of a snowpack is through the use of a radioisotope snow gauge. This utilizes gamma radiation from radioactive cobalt which is monitored using a radiation detector. A functional relationship relates emissions from the source to the snow water equivalent of the accumulating snowpack (Gray, 1970).

Snow courses are ideally located in areas which are representative of a given region. To provide an estimate of basin wide snowpack conditions several snow courses may be required, the number being a function of meteorological and physiographic variations within the area of interest, the desired accuracy, access, and available resources. In establishing a snow course local site characteristics with respect to meteorological conditions and topographic features must be

considered. Individual sampling points should be located in such a way as to avoid snow accumulation and melt variations due to interception by trees and drifting. To account for certain unavoidable variations a number of points are sampled and averaged. To account for the variation of precipation with elevation a range of elevations should be sampled; however, if this is not feasible the snow course should be located at the median elevation of the basin.

Once point values of snowpack parameters have been estimated these must be adapted to represent basin values either as an index or absolute measure. The utility of the index is dependent on its adequacy in representing watershed snowpack conditions rather than those of the point measure. Generally weighting factors are used to account for elevation variations. Even then it may represent changing snowpack conditions throughout the season or annually, but should not be used directly for quantitative assessments. If basin runoff is known, this may be used to develop a relationship between the basin index and streamflow.

While the first snow course in North America was established in 1910 to assess reservoir inflows, the history of the snow course network is considerably shorter in the Yukon River basin and Yukon Territory. The first snow courses in the Yukon Territory were established in 1965 at Whitehorse, Mayo and Watson Lake airports. These were prompted by the International Hydrological Decade, a United Nations sponsored event which was initiated to further the world's understanding of its water resources. These few snow courses were sampled by Transport Canada for AES, who wished to collect this information at existing weather stations. A few stations within the Yukon River basin were established earlier, however, with the Log Cabin station being established in 1958. Though this station is located in British Columbia, it was established by the Soil Conservation Service in Alaska, who wanted information on the Yukon River basin headwaters most likely to provide snow depth data for the operation of the White Pass Railway through the Coast Mountains to Skagway. (Snow survey work started in Alaska in 1951). A station was located in Atlin, British Columbia in 1964 by the British Columbia Water Investigations Branch who established several stations in northern British Columbia that year. The years 1965 and 1967 saw the establishment of two additional snow courses by the Soil Conservation Service at Eagle and Boundary, Alaska respectively, just outside the international boundary west of Dawson.

No further stations were established within the region until 1975 when DIAND estabished several stations in an attempt to better understand streamflow response in the Territory. Specifically, information was needed for flood and

volume forecasting. This coincided with the time DIAND adopted an active role in the development of the hydrometric network in the Territory. The established snow course sites were selected with the aid of AES and were located in or nearby basins comprising the then proposed regional hydrometric network. In some cases they were located at elevations which were thought to be representative of the basin conditions at proposed hydrometric stations.

These stations are listed in Table 29 and their locations shown in Figure 25. Six additional sites were also established; however, these were discontinued after one season of monitoring because they were all valley stations with an approximate elevation of 750 meters and were not thought to be representative on a basin wide scale. These stations were located at Teslin, Johnsons Crossing, Stewarts Crossing, Haines Junction, Faro and Kusawa Lake.

Six stations were established in 1976 within or nearby the Yukon River basin. Within the basin these are Meadow Creek near the South Canol Highway in the Nisutlin basin, Victoria Creek in the Nisling basin, Aishihik Lake Upper, which is near the divide between the Aishihik and Nisling basins, and Midnight Dome near Dawson in the Klondike basin. Stations were also established at Pine Lake airstrip near the divide between the Rancheria River and the Swift River and at Tischu River in the MacKenzie drainage but near the divide with the Hess basin.

A paucity of information in the St. Elias Mountains, Ross and Stewart River basins and Marsh Lake system was noted. Several stations were established over the next two years to meet these deficiencies. Stations were not established in the Coast Mountains or the Marsh Lake basin, however. A transect of five stations was established within the Kluane Park and other parts of the St. Elias Mountains (Burwash airstrip, Duke River, Felsite Creek, Bates River, and Stanley Creek). Two stations were established in the Pelly basin (Hoole and Twin Creeks) and one in the Stewart basin (Rogue River). A station was also established at Clinton Creek to provide site specific information for the mine site and Cassino Creek near the Yukon River downstream of the Selwyn River.

During 1980 three additional stations were established in the Alsek basin. Though these stations are outside the Yukon River basin they are close enough in proximity that they may be representative of portions of the basin.

In 1981 several transect stations were established in the Whitehorse area to determine the variation in snowpack characteristics with elevation during both accumulation and depletion periods. These were located on Mount McIntyre at elevations of 915, 1205 and 1355 meters. These were supplemented by the

TABLE 29 HISTORICAL YUKON RIVER BASIN AND NEARBY SNOW COURSES

STATION #	STATION NAME	ELEVATION (Meters)	LATITUDE (Degrees/Minutes)	LONGITUDE	PERIOD OF OPERATION
Yukon River Basin					
09AA-SC1	Tagish	1,080	60 17	134 11	1975
09AA-SC2	Montana Mountain	1,020	60 08	134 44	1975
09AA-SC3	Log Cabin	880	59 46	134 58	1958
09AA-SC4	Atlin	730	59 34	133 42	1964
09AB-SC1A	Mt. McIntyre A	915	60 40	135 07	1981
09AB-SC1B	Mt. McIntyre B	1,130	60 40	135 08	1975
09AB-SC1C	Mt. McIntyre C	1,205	60 39	135 09	1981
09AB-SC1D	Mt. McIntyre D	1,355	60 38	135 09	1981
09AB-SC2	Whitehorse Airport	700	60 42	135 04	1965
09AB-SC3	McClintock	685	60 36	134 26	1981
09AB-SC4	Chadburn Lake	710	60 39	134 58	1983
09AB-SC5	Long Lake	671	60 45	135 02	1983
09AD-SC1	Meadow Creek	1,235	60 35	133 05	1976
09AH-SC1	Mt. Berdoe	1,035	62 02	136 14	1975
09BA-SC1	Ross River Hill	975	61 56	132 28	1975
09BA-SC2	Twin Creeks	900	62 40	131 07	1977
09BA-SC3	Hoole River	1,085	61 28	131 28	1977
09BC-SC1	Rose Creek (Faro)	1,080	62 20	133 23	1975
09CA-SC1	Victoria Creek	990	62 01	137 04	1976
09CA-SC2	Aishihik Lake Upper	1,160	61 43	137 20	1976
09CA-SC3	Burwash Airstrip	810	61 23	139 03	1977
09CA-SC4	Duke River	1,465	61 07	138 53	1978
09CB-SC1	Beaver Creek	655	62 25	140 51	1975
09CD-SC1	Casino Creek	1,065	62 44	138 48	1977
09CD-SC2	Fort Selkirk	454	62 49	137 22	1983
09DA-SC1	Rogue River	762	63 31	132 05	1978
09DA-SC2	MacMillan Pass	1,495	63 11	130 10	1981 - 1982
09DC-SC1	Mayo Airport	495	63 38	135 53	1965

TABLE 29 HISTORICAL YUKON RIVER BASIN AND NEARBY SNOW COURSES (Continued)

STATION #	STATION NAME	ELEVATION (Meters)	LATITUDE (Degrees/Minutes)	LONGITUDE	PERIOD OF OPERATION
Yukon River Basin (Continued)					
09DD-SC1	Calumet	1,310	63 55	135 24	1975 - 1982
09DD-SC2	Keno Hill	1,355	63 56	135 15	1975 - 1981
09DD-SC3	Stewart Crossing	610	63 22	136 41	1983
09EA-SC1	King Solomon Dome	1,080	63 53	138 56	1975
09EA-SC2	Grizzly Creek	1,220	64 26	138 17	1975
09EB-SC1	Midnight Dome	885	64 04	139 24	1976
09EC-SC1	Eagle Village	275	64 48	141 08	1965
09EC-SC2	Boundary	1,005	64 05	141 27	1967
09EC-SC4	Clinton Creek	335	64 24	140 37	1977
Alsek River Basin					
08AA-SC1	Canyon Lake	1,160	61 07	136 59	1975
08AA-SC2	Dezadeash	725	60 22	137 04	1980
08AB-SC1	Felsite Creek	762	60 34	138 05	1978
08AB-SC2	Bates River	686	60 09	137 56	1978
08AB-SC3	Summitt	985	60 52	137 38	1980
08AC-SC1	Stanley Creek	925	59 56	136 48	1977
08AC-SC2	Takhanne	762	60 07	136 59	1980
Liard River Basin					
10AA-SC1	Watson Lake Airport	685	60 07	128 50	1965
10AA-SC3	Pine Lake Airstrip	995	60 06	130 56	1976
McKenzie River Basin					
10HA-SC1	Tsichu River	1,564	63 18	129 49	1976

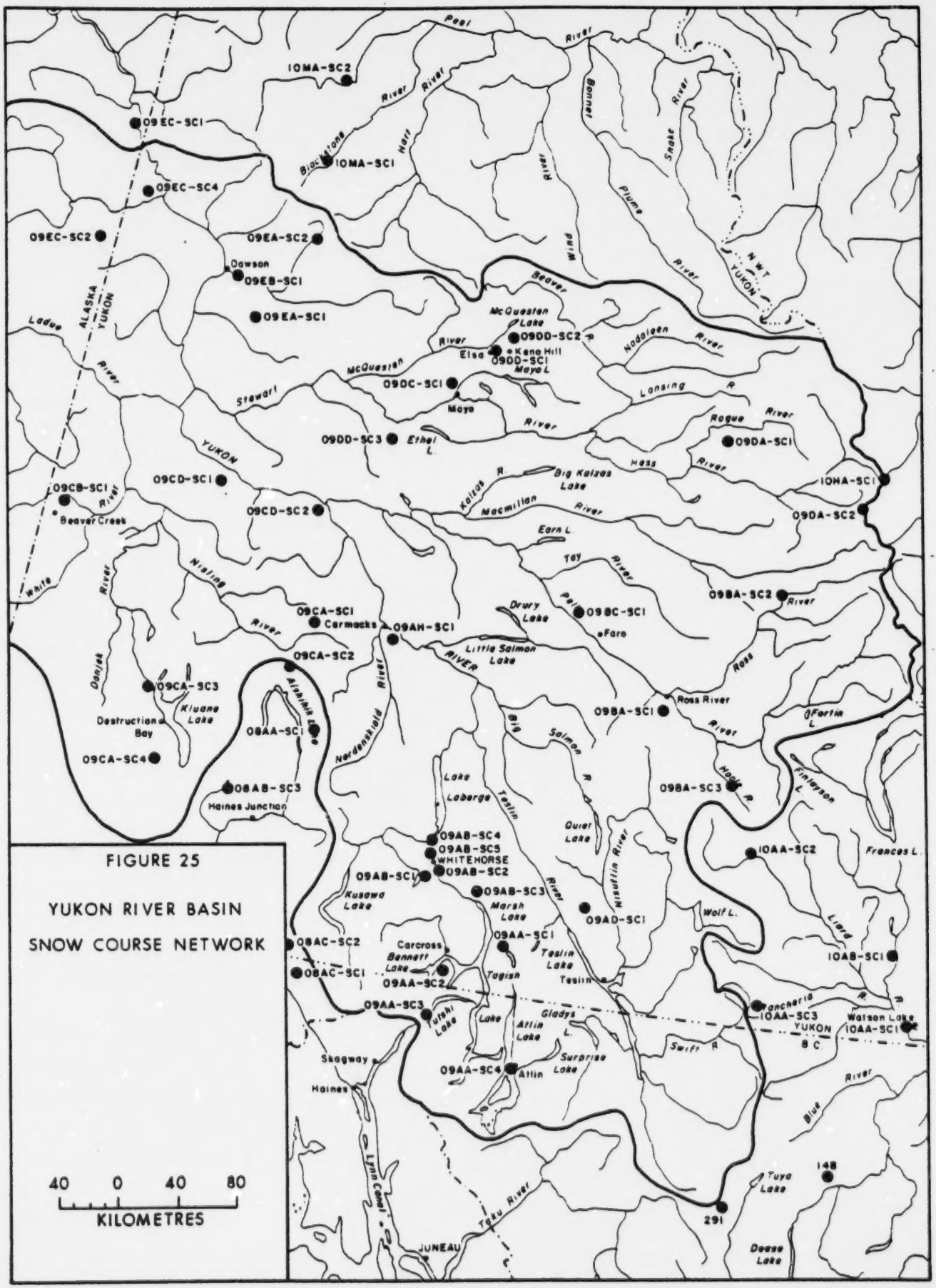


FIGURE 25

YUKON RIVER BASIN

SNOW COURSE NETWORK

40 0 40 80

KILOMETRES

previously established station at 1130 meters. The established relationship may be transferred to other areas to remove some of the variability between measurements obtained from different elevations. Snow courses were also established at McLintock to provide information for the upper Yukon and at Macmillan Pass to provide information for the upper Stewart River basin.

In 1982 discussions were initiated by the Department of Renewable Resources of the Yukon Territorial Government to determine the feasibility of establishing a large number of stations within the Territory to provide information for wildlife migration patterns. Though the program did not proceed, two test snow courses were established near Whitehorse at Long Lake and Chadburn Lake. Stations were also established at Fort Selkirk and Stewart Crossing.

Until 1979 the operation of the snow course network, including much of the actual sampling, maintainence, quality control, archiving and publication was carried out by DIAND in Whitehorse. Some of the actual surveys were carried out by paid observers and volunteers from within DIAND and other government and outside agencies. In 1979 in an informal agreement with AES through a Memorandum of Understanding, many of these responsibilities were transferred to AES. The work was carried out on a cost recoverable basis where DIAND transferred funds to AES to cover the salary of a technician and the operating and maintenance costs. This allowed for a more dedicated approach to the sampling program which previously was one of the many tasks performed by DIAND and sometimes did not receive adequate attention.

As discussed under the meteorological section, a formal MOU was sought for several years. As a restraint measure, however, the informal agreement was terminated during 1983 with the withdrawal of one of the two Meteorological Inspector positions. Since DIAND has also been subjected to staffing reductions this action seriously jeopardizes the future of the snow survey program.

4.1 Snow Course Network Assessment

Very little information is available regarding the optimum density of a snow course network. As mentioned above, this is a function of climatic and physiographic variations and the required degree of accuracy. As with the other data networks, both baseline and site specific needs should be addressed. According to WMO guidelines (World Meteorological Organization, 1970) snow course density should approximate that of a precipitation network. Values of one snow course for

2000 to 3000 square kilometers and 5000 square kilometers are cited for physiographically variable and flat areas respectively. No definition is presented for a physiographically variable area; however, it is mentioned that snow courses should be specially adapted in mountain areas.

Few rigorous studies have been carried out in the past to assess the adequacy of a particular snow course network. The analysis carried out for the MacKenzie River Basin Network Assessment was subjective in nature and based on the intuitive consideration of watershed coverage.

The Water Management Branch of the British Columbia Ministry of Environment is in the process of assessing the British Columbia snow course network for site specific requirements (Weiss, 1983). The network provides relatively long term information, having started in 1935. As with the other data collection networks, the British Columbia snow course network was established to provide site specific information. Stations were established over the years to provide information for various reasons, with none being discontinued unless they were damaged. As a result it was suspected that the snowpack characteristics of a given snow course may be similar to those of a nearby snow course and therefore possibly provide redundant information. To determine the degree of interrelationship between pairs of stations a correlation analysis was carried out. It was suggested that where two stations appeared to be highly correlated further analysis should be carried out to qualify the results.

Since the snow course network within the Yukon River basin is relatively recent, record lengths are overall too short for the application of statistical techniques. Selected pairs of stations may have record lengths which approach that required for statistical definition, though these have not been identified. The snow course network has been assessed with respect to baseline and site specific coverage with the objective of identifying data gaps and potentially redundant stations. Climatic regions as defined by Wahl (1983) were used as the basis for the assessment of baseline needs. Each climatic region was assessed to insure an adequate distribution of stations throughout. Water management concerns only are considered in terms of baseline requirements, though other disciplines may have a need for this information as well. Site specific requirements were likewise assessed with the intention of identifying data gaps and redundant stations for both future design purposes and current operational needs.

4.11 Baseline Requirements

The climatic regions within the Yukon River basin have been described above and these are noted in Figure 12. The objective of this section is to subjectively assess the adequacy of each region with respect to transferring snowpack information to ungauged areas. Stations which are thought to provide unrepresentative information are also discussed in this section.

St. Elias - Coastal Mountain Regions

With the exception of the northern and southern portions of this region it has relatively dense coverage with the seven existing stations. No information is available for the upper White-Donjek area. A station located on the divide between these basins would provide valuable information. This deficiency has been noted by Gray (1984) during compilation of snowpack statistics for operational purposes. Similarly, there is little information for portions of the upper Yukon basin. Specifically, a snow course is required to provide information on snowpack characteristics of the upper Atlin-Tagish system. Though a station does exist at Atlin, it is located in the valley and is not representative of higher elevations. A station at a higher location is supported by the British Columbia Water Management Branch (Coulson, 1983).

Three of the existing stations which are located near the Haines Highway are at relatively low elevations and in close proximity to one another. Though these are outside the Yukon River basin they may be representative of headwater areas of the Takhini River basin. These snow courses should be examined in greater detail. If no site specific need exists for these one may be moved or discontinued without a loss of a great deal of information. The Stanley Creek station which lies both outside the Yukon River basin and the Yukon Territory and is presently sampled by DIAND may be a candidate.

Upper Yukon Basin

This region, with 17 snow courses, has the greatest density of all the climatic regions within the basin. Eight of these are clustered around Whitehorse, but even still the coverage is reasonably adequate in terms of baseline coverage. One exception is the upper Teslin basin which, as with the other data collection networks, is unrepresented in the upper Teslin basin of British Columbia. A snow course located in the higher elevations of the Teslin-Jennings River basins would

provide valuable baseline information for water management purposes. This location is supported by the British Columbia Water Management Branch who have proposed this snow course for possible inclusion in their baseline network (Coulson, 1983). A second possible baseline deficiency exists in the upper Nordenskiold basin. This basin has a hydrometric station at the lower end, but lacks input information.

Three existing stations should be examined in greater detail to determine if the information they provide is representative. The McClintock snow course in the McClintock River basin which flows into Marsh Lake is at a relatively low elevation (685 meters) and may not adequately characterize the snowpack of the area. Similarly, the recently established Chadburn and Long Lake snow courses near Whitehorse are at 710 and 670 meters respectively. If these snow courses serve no site specific needs they may be better located at higher elevations.

Central Yukon Basin

This area represents the largest climatic region within the Yukon River basin, encompassing much of the Yukon Plateau adjacent the main stem of the Yukon River and Pelly River. A large gap exists in the interior Yukon basin in the proximity of the Stewart River area. Two stations recently established at Fort Selkirk and Stewart Crossing provide a beginning to fulfilling the existing deficiencies. However, both of these are at relatively low elevations, located at 450 and 610 meters respectively. These stations should be examined in greater detail to determine their suitability. As with much of the Yukon River basin and Yukon Territory, locations are often limited to readily accessible areas. If possible, a station should be established at a representative elevation.

In the southern portion of the region a major deficiency exists in the Pelly basin. A snow course station established in the middle reaches of the Pelly River basin would provide the missing information.

Pelly - Cassiar Mountains

The Pelly-Cassiar Mountains represents the smallest climatic region within the Yukon River basin. This zone does not itself contain any snow course stations, though several peripheral stations may provide representative information. Still, one or two well placed stations would provide useful baseline information. Ideally a station might be established at the median elevations of the Big Salmon River basin. Stations established adjacent the South Canol Highway in the vicinity of

Quiet Lake and the Robert Campbell Highway near the Little Salmon River may suffice.

Ogilivie - MacKenzie Mountain Regions

The Ogilivie-MacKenzie Mountain Regions represent the northern and western periphery of the Yukon River basin. This region is relatively long and narrow in places, and encompasses the upper reaches of the Macmillan and Stewart Rivers and portions of the Klondike and McQuesten River. This region is relatively well monitored with respect to baseline requirements; however, deficiencies are evident. Information is available for the Macmillan Pass area and along the North Canol Highway, which may be representative of portions of the Macmillan basin. These are relatively high elevation stations, however, and poses the same problems as a non-representative low elevation station. An additional deficiency exists in the middle elevations of the Stewart River. A station located in the Upper Stewart River drainage may satisfy this deficiency. Two stations in the Keno area have not been sampled during the past two years because of the limited nature of the mining operation. The Calumet and Keno Hill stations were sampled by volunteer observers from the mining operation. Measures should be taken to ensure that one of these stations be re-established to provide long term baseline information since they are representative of the McQuestion-Mayo Lake area.

4.12 Site Specific Requirements

The snow course network was evaluated to determine its adequacy in satisfying the site specific needs for both future planning and design purposes and for current uses. All existing stations were examined to determine if they are currently functional. It has been found that though a particular station may no longer be required for the reason it was initially established, it may serve a more recent site specific need or provide information for baseline purposes. The potential major developmental concerns have been discussed earlier. It is important that adequate design information be provided for these.

St. Elias - Coastal Mountains

No major mining or hydroelectric developments are proposed for this region. The existing snow courses within St. Elias Mountains and Kluane Park are sufficient to meet recreational needs; however, it may be necessary to increase

the network to provide information for the proposed road into the park. The existing snow courses adjacent the Haines Highway are adequate for road maintenance, and as mentioned in the previous section, these stations should be examined closer to determine if some redundancy exists. The Log Cabin station provides adequate maintenance and operating information for the Klondike Highway and White Pass Railway to Skagway and provides reservoir inflow information for the Whitehorse Rapids hydroelectric development.

Upper Yukon Basin

The proposed major mining developments within this region are adequately monitored. The Montana Mountain snow course is in very close proximity to the Venus mining development. The proposed hydroelectric developments do not for the most part have adequate coverage. A snow course is required in the median elevations of the upper Atlin basin to provide information on inputs to the system. Likewise similar data is required for the upper Teslin basin. The locations suggested for baseline stations in these areas would be suitable to satisfy these particular requirements.

As discussed above, inflows to the upper lakes system are not as well defined as they might be for present operational purposes. A snow course station located in the upper Tagish-Atlin area would provide additional information on water availability and may improve inflow forecasts and subsequent storage regulation for the Whitehorse Rapids hydroelectric plant.

The McClintock snow course provides inflow information to Marsh Lake, but as mentioned in the previous section, this station is probably located at an elevation which would provide unrepresentative information on water availability.

Central Yukon Basin

The mid-Yukon proposed hydroelectric development is within this region; however, information required for design purposes is better considered on a sub-basin basis. The Pelly (Hoole) proposal is well covered; however, additional design information could be utilized for the Pelly (Granite) project. This station could be collocated with the suggested baseline snow course. The existing Meadow Creek snow course is representative of the Squanga Creek basin.

A snow course at the median elevations of the Pelly River basin would also provide valuable information for the annual flood forecasting exercise at Ross River. Currently winter snowpack information is obtained from low elevation stations.

Adequate snow course information is available for the Dawson placer mining industry. The Clinton Creek snow course may no longer provide useful information since the mine is no longer in operation. If it were at a higher elevation it could most likely provide useful baseline information. Snow courses were established at Chadburn and Long lakes near Whitehorse as test stations to be part of the network proposed in the southern lakes area by the Yukon Territorial Government to study wildlife over wintering habits. Since this study will no longer go forward the utility of this information is in doubt. Similarly, the relatively low elevation Fort Selkirk and Stewart Crossing stations may not provide useful information unless they can be utilized for local purposes such as airstrip and highway maintenance respectively.

Pelly - Cassiar Mountains

The Livingston placer region is the only mining development within this region. The baseline station recommended above could also provide information for this area.

There is no proposed hydroelectric development within this region. A station established adjacent the South Canol Highway might provide useful information for road maintenance.

Ogilivie - MacKenzie Mountains

The Macmillan Pass proposed mining development is adequately covered with respect to snow course information. A long term station at the Tischu River is representative of the area. In addition, the currently discontinued Macmillan Pass station would probably be reactivated when exploration accelerates.

There is no station in the the Howards Pass proposed development area. Such a station would provide useful design and maintenance information. This is a remote area; therefore, it may not be cost effective. The surrounding stations should be examined to determine their representativeness of this area.

Due to the limited operation of the United Keno Mine in the Elsa area, the volunteer observers have discontinued sampling of the two snow courses. Attempts should be made to have at least one of these reactivated to insure a continuous record.

A snow course located in the median elevations of the Macmillan River basin would provide valuable inflow information for the proposed Pelly (Granite) hydroelectric development. The existing Grizzly Creek snow course on the Dempster Highway most likely provides adequate data for the proposed North Klondike hydroelectric development. One of the Keno Hill stations would, in addition to the previously mentioned reason, provide inflow information for the operation of the existing Mayo Lake hydroelectric plant.

A snow course located in the median elevations of the Stewart River basin would provide valuable snowpack data for spring flood forecasting for Mayo. Presently, low elevation information is used for this purpose. Use of the more representative information may improve the accuracy of the predictions. A recommended baseline station for this area may provide information suitable for this purpose.

The existing Dempster and North Canol Highways have adequate snowpack information for maintenance and design purposes.

5.0 RECOMMENDATIONS AND CONCLUSIONS

The existing data collection networks within the Yukon River basin have been assessed to determine their adequacy for providing site specific and baseline data. Each of the component networks was evaluated independently with the objective of identifying data deficiencies and redundant stations. This section summarizes the recommendations of the component network assessments. Descriptions of the networks and the rationale used in arriving at the specific recommendations are discussed in the relevant sections.

During the actual evaluation exercise only minimal attempts were made to coordinate the various component networks. Integration optimizes an information data base by adopting a basin overview approach. In doing so, this provides basic information on the interaction of the various input processes which result in a particular basin response. Each component network within an overall hydrometeorological network complements the other members. Ideally, there should be several climatic stations for every one hydrometric station, but every hydrometric station should have a climate station within the basin. Upon establishing a functional relationship between discharge and climatic paramaters this information can be transferred to other nearby basins which have climatic stations within their boundaries.

Often collocation is considered to be synonymous with integration. This does not necessarily suggest that the various component stations should be located at specifically the same spot but, as discussed above, within the drainage basin. In theory, collocation results in an increased understanding of the various interrelated processes with a reduction in operating costs through the coordination of personnel and air charters. Often such coordination is not practical though, due to variable sampling schedules.

The concept of integration is not generally included in the overall network assessment; however, specific cases occur where stations from more than one component network have been recommended for establishment at the same location. This occasionally is the case with snow course and precipitation stations at higher elevations which in certain instances will provide a duplication of information. Collocation of snow courses and climatological stations are recommended in certain areas however to provide backup information or to determine a functional relationship between the two for transfer to other areas. During winter periods snow courses may be more accurate than precipitation gauges due to under catch and in

certain cases by over capping. While summarizing the specific recommendations of the assessment of the component networks further suggestions are made regarding the collocation of particular stations.

5.1 Recommendations

5.11 Hydrometric Networks

To maintain continuity it is desirable not to differentiate between the hydrometric networks operated by Water Survey of Canada and the Department of Indian Affairs and Northern Development. Where it was possible, this was the approach adopted. For the purposes of this study it is assumed that stations which have been identified to provide baseline or in some cases long term site specific information will be included in the network operated by WSC. Stations which are required for short term site specific purposes within the Yukon River basin will be included in the network operated by DIAND.

The correlation analysis which was carried out to determine the degree of interrelation between stations with the objective of identifying redundant stations was performed on the hydrometric stations operated by WSC only. No specific recommendations were made for eliminating stations, though it is suggested that the highly correlated pairs of stations be examined in greater detail.

All hydrometric stations were examined from an historical site specific viewpoint to determine their current utility. The station Takhini River near Whitehorse which is operated by WSC is thought to serve little purpose and should possibly be discontinued.

The hydrometric network operated by DIAND, as most data collection networks, was initially established to provide site specific information. The historical network was evaluated to determine whether individual stations were currently required for short term specific purposes. The majority of these were found to be no longer required. Twelve stations were recommended for retention to meet these needs.

The existing network was also assessed to determine its adequacy for satisfying long term baseline requirements. The objective was to select a number of optimally located stations which would represent the streamflow characteristics of a given hydrologic region. Record length and quality were additional criteria used for the selection, as well as the proximity of WSC hydrometric stations

draining smaller drainage basins. On this basis 24 stations were deleted from the historical network, while 12 were recommended for retention to provide baseline information. For the purposes of this study it is assumed that these will be incorporated into the network operated by WSC; therefore, they are listed there.

The adequacy of the existing hydrometric networks was also assessed with respect to baseline requirements to identify data gaps. Generally coverage of intermediate and large basins is adequate, though some deficient areas were identified. Coverage of small basins is less adequate. The network was also assessed to determine its adequacy to fulfill site specific requirements. Of the proposed major mining and hydroelectric developments, those in the eastern portion of the basin require additional data.

Several additional site specific stations have been recommended for current operational needs. The area most efficient in this respect is the upper lakes system. In addition, the modification of two existing stations and one proposed have been recommended to provide data on a real time basis. Recommended changes to the WSC hydrometric network are summarized in Table 30 and Figure 26.

5.12 Meteorological Networks

The meteorological network consists of two component networks, the meteorological network which is used primarily for weather forecasting purposes, and the climatological network which is used for climate definition purposes. The former component is generally adequate for weather prediction purposes, though some gaps have been identified. The synoptic network does not provide adequate information for the Selwyn Mountains area. Gaps in the hourly network are evident in the central Yukon basin and the Selwyn Mountains, while the upper air network does not provide coverage for the northern and eastern peripheral areas of the basin.

The climatological station network serves both baseline and site specific needs. The baseline network, which consists of the ordinary climate station network and the supplementary station network, is less adequate than the meteorological network. In general, many of the existing meteorological stations are located on the valley floor and therefore are not representative of higher elevations. Several large gaps, primarily in remote areas, have been identified. Though these are located throughout the Yukon River basin the most deficient areas are

FIGURE 26
YUKON RIVER BASIN
WATER SURVEY OF CANADA
HYDROMETRIC NETWORK
Recommended Changes
Streamflow Station.
Discontinued Streamflow Station.
Water Level Station.
Discontinued Water Level Station.
40 0 40 80
KILOMETRES
10MA001
10MA002
10MA003
10MB003
10MB004
09MB001
09EC002
09EB001
Dawson
09EA003
09EA004
09EB003
09EA005
09EB002
09D0003
09C0001
09D0004
09C0002
09D0002
09C0001
09C0004
09C0005
09C0003
09B0002
09C8001
09AH003
09C8001
09CA003
09AH001
09AH004
09CA002
09AC004
09AA008
09AA007
09CA001
80AA009
08AA005
08AA010
08AB001
08AA003
09AF001
09AB009
09AC003
09AB010
09AC001
09AC002
09AC005
09AA001
WHITEHORSE
09AB001
09AB008
09AB004
09AA001
09AA009
09AA002
09AA010
09AA013
09AA003
09AA014
09AA016
09AA015
09AA008
09AA001
09AE001
09AD001
09AE002
09AE004
09AE003
10AA002
10AA001
10AB001
10AC004
10AC005
10AC002
10AC003
10HA002
09DA001
09BB002
09BB001
09BC003
09BC004
09AG001
09AG002
09AD002
09BA001
10AB002
09BB003
09BB002
09BB004
09BB001
JUNEAU
Dawson
Beaver Creek
Destruction Bay
Haines Junction
WHITEHORSE
Carcross
Skagway
Haines
Watson Lake
Frances L
Wolf L
Finlayson L
Fort Nelson
YUKON T.
B.C.
ALASKA
YUKON
Porcupine River
Peel River
Bonnet Plume River
Snake River
Blackstone River
Hart River
Ogilvie River
Eagle River
Beaver River
Klondike River
Stewart River
Pelly River
Macmillan River
Big Salmon River
Little Salmon River
Nisutlin River
Teslin River
Liard River
Nahanni River
Kechika River
Rancheria River
Dease River
Tuya River
Taku River
Stikine River
Lynn Canal
Kluane Lake
Aishihik Lake
Laberge Lake
Marsh Lake
Tagish Lake
Teslin Lake
Atlin Lake
Dease Lake
Tuya Lake
McQuesten Lake
Mayo
Elsa
Keno Hill
Ethel L.
Big Kalzas Lake
Earn L.
Drury Lake
Fort
Carmacks
Ross River
Quiet Lake
Glades
Swift R.
Finlayson L.
Frances L.
Wolf L.
Fort Nelson
Watson Lake
Rancheria
Tuya Lake
Dease Lake

TABLE 30 RECOMMENDED CHANGES TO HYDROMETRIC NETWORK OPERATED BY WATER SURVEY OF CANADA

MAP NO.	STATION IDENTIFICATION	RECOMMENDED INSTRUMENTATION	RATIONALE	COMMENTS
1	White River near the mouth	Water Level Recorder and Metering Cross Section	- Baseline; - Large basin; - St. Elias Mountians; - Proposed major stream station (WSC, 1975).	- Reactivate Yukon River below Stewart River; - Not possible to establish a station on White River; - This information could be obtained by subtraction.
2	Dry Creek #2 at Km. 1905, Alaska Highway	Water Level Recorder and Metering Cross Section	- Baseline & site specific; - Small basin; - Shakwak and Kluane Ranges; - Highway upgrading and pipeline corridor.	- Currently monitored by DIAND.
3	Snag Creek at Km. 1945.6, Alaska Highway	Water Level Recorder and Metering Cross Section	- Baseline & site specific; - Small basin; - Kluane Plateau and Range; - Highway upgrading and pipeline corridor.	- Currently monitored by DIAND.
4	Edith Creek (Koidern River) at Km. 1844.2, Alaska Highway	Water Level Recorder and Metering Cross Section	- Baseline & site specific; - Small basin; - Kluane Plateau and Ruby Range; - Highway upgrading and pipeline corridor; - Proposed regional station (WSC, 1971).	- Currently monitored by DIAND.

TABLE 30 RECOMMENDED CHANGES TO HYDROMETRIC NETWORK OPERATED BY WATER SURVEY OF CANADA (Continued)

MAP NO.	STATION IDENTIFICATION	RECOMMENDED INSTRUMENTATION	RATIONALE	COMMENTS
5	Christmas Creek at Km. 1687.8, Alaska Highway	Water Level Recorder and Metering Cross Section	- Baseline & site specific; - Eastern side of Shakwak Valley and Kluane Range; - Highway upgrading and pipeline corridor.	- Currently monitored by DIAND.
6	09AC001 Takhini River near Whitehorse	Discontinue	- Only 20% increase in volume over upstream station Takhini at outlet of Kusawa Lake; - High correlation with upstream station; - No apparent site specific need.	
7	Mendenhall Creek at Km. 1557.9, Alaska Highway	Water Level Recorder and Metering Cross Section	- Baseline & site specific; - Small basin; - Coast Mountains and Lewes Plateau; - Highway upgrading and pipeline corridor.	- Currently monitored by DIAND.
8	Ibex River near Whitehorse	Water Level Recorder and Metering Cross Section	- Baseline & site specific; - Small basin; - Coast Mountains; - Pipeline corridor.	- Currently monitored by DIAND.

TABLE 30 RECOMMENDED CHANGES TO HYDROMETRIC NETWORK OPERATED BY WATER SURVEY OF CANADA (Continued)

MAP NO.	STATION IDENTIFICATION	RECOMMENDED INSTRUMENTATION	RATIONALE	COMMENTS
9	Teslin River at inlet of Teslin Lake	Water Level Recorder and Metering Cross Section	- Baseline; - Intermediate-large basin; - Kawdy Plateau; - Proposed major stream station (WSC, 1975).	
10	Squanga Creek at outlet of Squanga Lake	Water Level Recorder and Metering Cross Section	- Site specific; - Potential hydroelectric development.	
11	Tagish Lake	Water Level Recorder	- Site specific; - Existing reservoir operation.	
12	Six Mile River near Tagish	Metering Cross Section	- Site specific; - Existing reservoir operation.	- Relate discharge to Tagish and Marsh Lake stages.
13	Bennett Lake at outlet	Metering Cross Section	- Site specific; - Existing reservoir operation.	- Relate discharge to Bennett and Nares (Tagish) Lake stages.
14	09AB004 Marsh Lake	Provide real time data capability	- Site specific; - Existing reservoir operation.	

TABLE 30 RECOMMENDED CHANGES TO HYDROMETRIC NETWORK OPERATED BY WATER SURVEY OF CANADA (Continued)

MAP NO.	STATION IDENTIFICATION	RECOMMENDED INSTRUMENTATION	RATIONALE	COMMENTS
15	Judas Creek	Water Level Recorder and Metering Cross Section	- Baseline & site specific; - Small basin; - Pelly Mountains and Teslin Plateau; - Highway upgrading and pipeline corridor.	- Currently monitored by DIAND.
16	Nisling River near the mouth	Water Level Recorder and Metering Cross Section	- Baseline; - Large basin; - Nisling & Kluane Ranges; - Proposed major stream station (WSC, 1975).	
17	Sixty Mile River near the mouth	Water Level Recorder and Metering Cross Section	- Baseline; - Intermediate basin; - Western portion of the Klondike Plateau.	
18	Ladue River near the mouth	Water Level Recorder and Metering Cross Section	- Baseline; - Large basin; - Western portion of the Klondike Plateau.	- Secondary station; - Sixty Mile may be somewhat representative.
19	Clinton Creek near Clinton Creek	Water Level Recorder and Metering Cross Section	- Site specific; - Long-term information required to monitor Cassiar Asbestos mine abandonment program.	- Currently monitored by DIAND.

TABLE 30 RECOMMENDED CHANGES TO HYDROMETRIC NETWORK OPERATED BY WATER SURVEY OF CANADA (Continued)

MAP NO.	STATION IDENTIFICATION	RECOMMENDED INSTRUMENTATION	RATIONALE	COMMENTS
20	Pelly River below Fortin Creek	Water Level Recorder and Metering Cross Section Real time data capability	- Baseline & site apeceific; - Large basin; - Western slopes of Logan Mountains and Pelly Plateau; - Potential hydroelectric development; - Existing flood forecasting utility; - Proposed major stream station (WSC, 1975).	
21	180 Mile Creek at Km. 295.8, North Canol Highway	Water Level Recorder and Metering Cross Section	- Baseline & site specific; - Small basin; - MacMillan Plateau and; Anvil Range; - Highway upgrading.	- Currently monitored by DIAND.
22	Jennings River near the mouth	Water Level Recorder and Metering Cross Section	- Baseline; - Intermediate basin; - Transitional area; - Cassiar Mountains and the Kawdy Plateau; - Proposed major stream station (WSC, 1975).	- Basin response differs from Swift River.

TABLE 30 RECOMMENDED CHANGES TO HYDROMETRIC NETWORK OPERATED BY WATER SURVEY OF CANADA (Continued)

MAP NO.	STATION IDENTIFICATION	RECOMMENDED INSTRUMENTATION	RATIONALE	COMMENTS
23	Partridge Creek at Km. 1184.9, Alaska Highway	Water Level Recorder and Metering Cross Section	- Baseline & site specific; - Small basin; - Cassiar Mountains; - Highway upgrading and pipeline corridor.	- Currently monitored by DIAND.
24	Stewart River above Lansing River	Water Level Recorder and Metering Cross Section Real time data capability	- Baseline & site specific; - Large basin; - Selwyn Mountains; - Existing flood forecasting utility; - Proposed major stream station (WSC, 1975).	
25	North MacMillan River near the mouth	Water Level Recorder and Metering Cross Section	- Baseline; - Intermediate basin; - Hess Mountains and the MacMillan Plateau; - Transitional area.	- Secondary station; - Basin response differs from Hess River.
26	Boulder Creek at Km. 387.0, North Canol Highway	Water Level Recorder and Metering Cross Section	- Baseline & site specific; - Small basin; - Hess Mountains and the MacMillan Plateau; - Highway upgrading.	- Currently monitored by by DIAND.

the Selwyn Mountains and the southern headwater areas. Since observer stations are not feasible the most reasonable alternate means to obtain this data is through the use of some form of automatic reporting. This may be cost prohibitive, however, and the necessary technology is not currently available in Yukon Territory.

The supplementary climatological network consists of specific purpose networks which within the Yukon River basin are primarily long term precipitation stations. From a water management point of view precipitation is generally the most important element. For the evaluation of the baseline storage precipitation network all stations which report precipitation amounts were included. Several large gaps have been identified.

The recording precipitation network provides information on precipitation intensity and duration. Major gaps have been identified in several areas throughout the basin.

The spatial distribution of storage and recording precipitation stations was also assessed to determine their adequacy to meet site specific needs. The proposed major mining developments are adequately monitored with the exception of Howards Pass, which should be instrumented with a recording station.

The proposed major hydroelectric developments generally require additional climatological information. Precipitation stations are recommended for the median elevations of the Pelly, the upper Teslin and upper Atlin areas.

Additional stations are also recommended for current operational requirements. A recording precipitation and temperature station in the headwater areas of Bennett Lake would provide valuable inflow information. Similarly, recording precipitation in the median elevations of the Pelly and Stewart River basins would provide information for flood forecasting. Ideally, the recommended stations on the upper Yukon, Pelly and Stewart would provide information on a real time basis. Recommended changes to the meteorological networks are summarized in Table 31 and Figure 27.

TABLE 31 RECOMMENDED CHANGES TO METEOROLOGICAL NETWORK

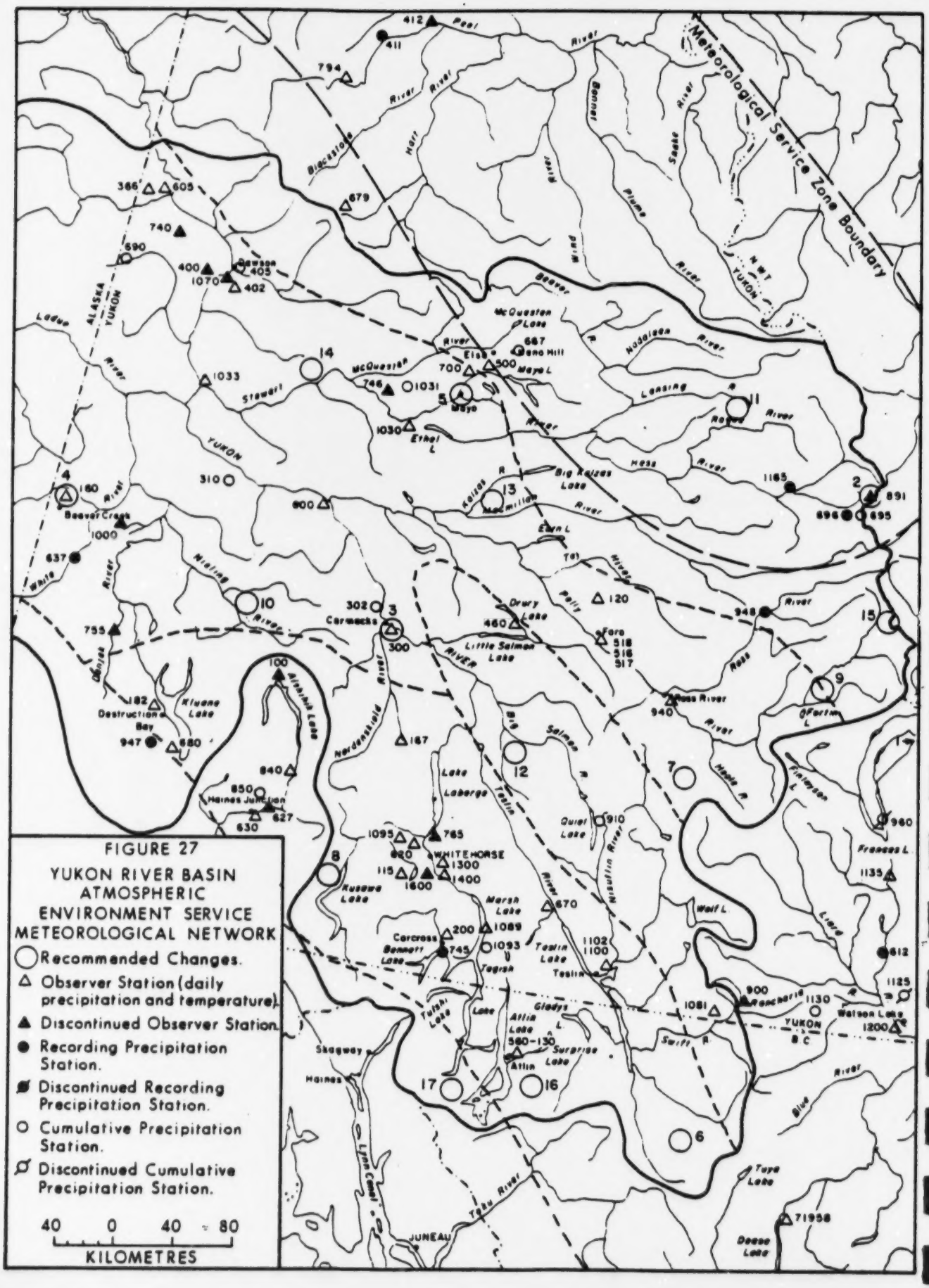
MAP NO.	STATION IDENTIFICATION	RECOMMENDED INSTRUMENTATION	RATIONALE	COMMENTS
1	Tungsten	- Provide synoptic and hourly reporting.	- Baseline; - Selwyn Mountains.	
2	Tischu River	- Reactivate station; - Synoptic reporting; - Hourly reporting.	- Baseline; - Selwyn Mountains.	
3	Carmacks	- Provide hourly reporting.	- Baseline; - Central Yukon Plateau.	
4	Beaver Creek	- Provide hourly reporting.	- Baseline; - Central Yukon Plateau.	- Established October 1983.
5	Mayo	- Provide upper air observations.	- Baseline; - Northern Yukon Plateau.	- Some international aviation requirements.
6	Upper Teslin	- Ordinary climatological station; - Recording precipitation.	- Baseline & site specific; - Kawdy Plateau and Cassiar Mountains; - Potential hydroelectric development.	- No observer for ordinary climatological station; - Establish recording precipitation station.
7	Upper Nisutlin-Hoole	- Ordinary climatological station.	- Baseline; - Pelly Mountains.	- No observer for ordinary climatological station; - Review need.
8	Kusawa area	- Ordinary climatological station.	- Baseline; - Coast Mountains.	- No observer for ordinary climatological station; - Review need.

TABLE 31 RECOMMENDED CHANGES TO METEOROLOGICAL NETWORK (Continued)

MAP NO.	STATION IDENTIFICATION	RECOMMENDED INSTRUMENTATION	RATIONALE	COMMENTS
9	Mid-Pelly	- Ordinary climatological station; - Recording precipitation and temperature; - Real time capability.	- Baseline & site specific; - Pelly Plateau; - Potential hydroelectric development; - Existing flood forecasting utility.	- No observer for ordinary climatological station; - Establish recording precipitation and temperature station with real time capability.
10	Mid-Nisling	- Ordinary climatological station; - Recording precipitation.	- Baseline; - Klonkike Plateau and Kluane Plateau.	- No observer for ordinary climatological station; - Establish recording precipitation station.
11	Mid-Hess Upper Stewart	- Ordinary climatological station; - Recording precipitation and temperature; - Real time capability.	- Baseline & site specific; - Selwyn Mountains and Stewart Plateau; - Existing flood forecasting - utility.	- No observer for ordinary climatological station; - Establish recording precipitation and temperature station with real time capability.
12	Mid-Teslin Big Salmon	- Ordinary climatological station; - Recording precipitation.	- Baseline; - Lewes Plateau and Pelly Mountains.	- No observer for ordinary climatological station; - Establish recording precipitation station.
13	Lower Macmillan	- Ordinary climatological station; - Recording precipitation.	- Baseline; - Lewes Plateau.	- No observer for ordinary climatological station; - Establish recording precipitation station.

TABLE 31 RECOMMENDED CHANGES TO METEOROLOGICAL NETWORK (Continued)

MAP NO.	STATION IDENTIFICATION	RECOMMENDED INSTRUMENTATION	RATIONALE	COMMENTS
14	Lower Stewart	- Recording precipitation.	- Baseline; - Klondike Plateau.	
15	Howards Pass	- Recording precipitation.	- Site specific; - Potential mining development. - Potential hydroelectric development.	
16	Upper Atlin	- Recording precipitation.	- Baseline & site specific; - Tealin Plateau and Tagish highlands; - Potential hydroelectric development.	
17	Upper Yukon-Tagish	- Recording precipitation and temperture station; - Real time capability.	- Site specific; - Existing reservoir operation.	


Meteorological Service Zone Boundary
ALASKA
YUKON
YUKON
N W T
Dawson
Mayo
WHITEHORSE
Carcross
Haines Junction
Destruction Bay
Beaver Creek
Carmacks
Faro
Ross River
Watson Lake
Teslin
Atlin
Skagway
Haines
JUNEAU
Little Salmon Lake
Lake Laberge
Kluane Lake
Aishihik Lake
Russell Lake
Bennett Lake
Tagish
Marsh Lake
Quiet Lake
Frances L
Wolf L
Gladys L
Surprise Lake
Taku River
Teslin River
Big Salmon R
Nisutlin River
Swift R
Hess River
Pelly River
Ross River
Macmillan River
Stewart River
Beaver River
Hodgson River
Lansing R
Nahanni River
Liard River
Blue River
Peel River
Bonnet Plume River
Snake River
Arctic Red River
Hart River
Bell River
Rat River
Porcupine River
Eagle
Fort McPherson
Inuvik
Aklavik
Tuktoyaktuk
Norman Wells
Fort Simpson
Fort Nelson
Fort St. John
Dawson Creek
Prince George
Prince Rupert
Whitehorse
Yukon
B C
Alaska
Mackenzie
Arctic Ocean
Beaufort Sea
Hudson Bay
Alberta
Saskatchewan
Manitoba
Ontario
Quebec
Pacific Ocean
Gulf of Alaska
Hudson Strait
Labrador Sea
Baffin Island
Greenland
Newfoundland
Nova Scotia
New Brunswick
Prince Edward Island
Gulf of St. Lawrence
Lake Superior
Lake Huron
Lake Erie
Lake Ontario
Lake Michigan
Lake Winnipeg
Great Slave Lake
Great Bear Lake
Athabasca
Peace River
Slave River
Liard River
Fraser River
Columbia River
Kootenay River
Red River
Assiniboine River
Saskatchewan River
Churchill River
Nelson River
Winnipeg River
Ottawa River
St. Lawrence River
Hudson Bay
James Bay
Ungava Bay
Labrador

5.13 Snow Course Networks

The snow course network, similar to the other data collection networks, was assessed to determine its adequacy to meet both baseline and site specific requirements. Several deficient areas have been identified, notably the Selwyn Mountains and upper Yukon basin. Also, several existing stations are suspected to be at unrepresentative low elevations.

Deficiencies in the baseline network were identified in nine areas. In addition, six existing snow courses may be too low in elevation and should be examined in greater detail to determine their suitability.

Several site specific deficiencies have been identified. In many cases they coincide in location to the recommended baseline stations providing additional justification for establishment. This is the case with six of the nine recommended stations. Two stations have been recommended to be discontinued, while four have been identified for further examination. It is also recommended that recording snow courses be established at inaccessible locations. The mid-Pelly or upper Stewart areas would be suitable candidate locations for establishment of such stations. Real time capability for providing data has been recommended in a few cases. Recommended changes to the snow course networks are summarized in Table 32 and Figure 28.

5.2 Conclusions

The various hydrometeorological data collection networks within the Yukon River basin have been assessed to determine their adequacy with respect to baseline and site specific requirements. A baseline network will ideally provide the basis for transferring information to any point within the area of interest, while a site specific network is required for current operational purpose or to provide information for proposed developments. In addition to data gaps, the various component networks were also evaluated to identify redundant stations. These networks include the hydrometric networks operated by the Water Survey of Canada and the Yukon Region of the Department of Indian Affairs and Northern Development, the meteorological network operated by the Atmospheric Environment Service, and the snow course network, operated by the British Columbia Ministry of Environment and the Department of Indian Affairs and Northern Development.

TABLE 32 RECOMMENDED CHANGES TO SNOW COURSE NETWORK

MAP NO.	STATION IDENTIFICATION	RECOMMENDED INSTRUMENTATION	RATIONALE	COMMENTS
1	Upper White-Donjek	- 10 point course.	- Baseline; - Kluane Range.	
2	Upper Atlin-Tagish	- Pressure pillow; - Real time capability.	- Baseline & site specific; - Coast Mountains; - Existing reservoir operation; - Potential hydroelectric development.	- Co-locate with climate station.
3	08AC-SC1 Stanley Creek	- Examine station records.	- In close proximity to 08AC-SC2; - May provide same information.	- Discontinue if information is redundant.
4	Upper Teslin-Jennings	- 10 point course.	- Baseline & site specific; - Kawdy Plateau; - Potential hydroelectric development.	
5	09AB-SC3 McClintock	- Examine station location.	- Elevation may be too low to be representative.	- Relocate at higher elevation if found not representative.
6	09AB-SC4 Chadburn Lake	- Examine station record.	- No current site specific - Elevation may be too low to be representative.	- Discontinue if no site specific need.

TABLE 32 RECOMMENDED CHANGES TO SNOW COURSE NETWORK (Continued)

MAP NO.	STATION IDENTIFICATION	RECOMMENDED INSTRUMENTATION	RATIONALE	COMMENTS
7	09AB-SC5 Long Lake	- Examine station record.	- No current site specific - Elevation may be too low to be representative.	- Discontinue if no site specific need.
8	Upper Nordenskiold	- 10 point course.	- Baseline; - Kluane Plateau.	
9	Mid-Yukon (Stewart)	- 10 point course.	- Baseline; - Kluane Plateau.	- Conditional on examination of 09CD-SC2 and 09DD-SC3.
10	09CD-SC2 Fort Selkirk	- Examine station location.	- Elevation may be too low to be representative.	- Discontinue if found not representative or if no site specific need.
11	09DD-SC3 Stewart Crossing	- Examine station location.	- Elevation may be too low to be representative.	- Discontinue if found not representative or if no site specific need.
12	Mid-Pelly	- Pressure pillow; - Real time capability.	- Baseline & site specific; - Pelly Plateau; - Potential hydroelectric development; - Existing flood forecasting utility.	- Co-locate with climate station.
13	Mid-Big Salmon	- 10 point course.	- Baseline & site specific; - Cassiar Mountains; - Existing placer mining area.	- South Canol Highway may be alternate location.

TABLE 32 RECOMMENDED CHANGES TO SNOW COURSE NETWORK (Continued)

MAP NO.	STATION IDENTIFICATION	RECOMMENDED INSTRUMENTATION	RATIONALE	COMMENTS
14	Upper Stewart	- Pressure pillow; - Real time capability.	- Baseline & site specific; - Selwyn Mountains and Stewart Plateau.	- Co-locate with climate station.
15	Mid-Macmillan	- 10 point course.	- Baseline & site specific; - MacMillan Plateau; - Potential hydroelectric development.	
16	Howards Pass	- 10 point course.	- Site specific; - Potential mining development. - Potential hydroelectric development.	
17	09DD-SC2 Keno Hill	- Re-establish.	- Important baseline and site specific data; - Stewart Plateau; - Existing mining development. - Existing reservoir operation.	- 09DD-SC1, Calumet, alternate for re-establishment.
18	09EC-SC4 Clinton Creek	- Examine station records.	- May be no current site specific need.	- Discontinue if no site specific need.

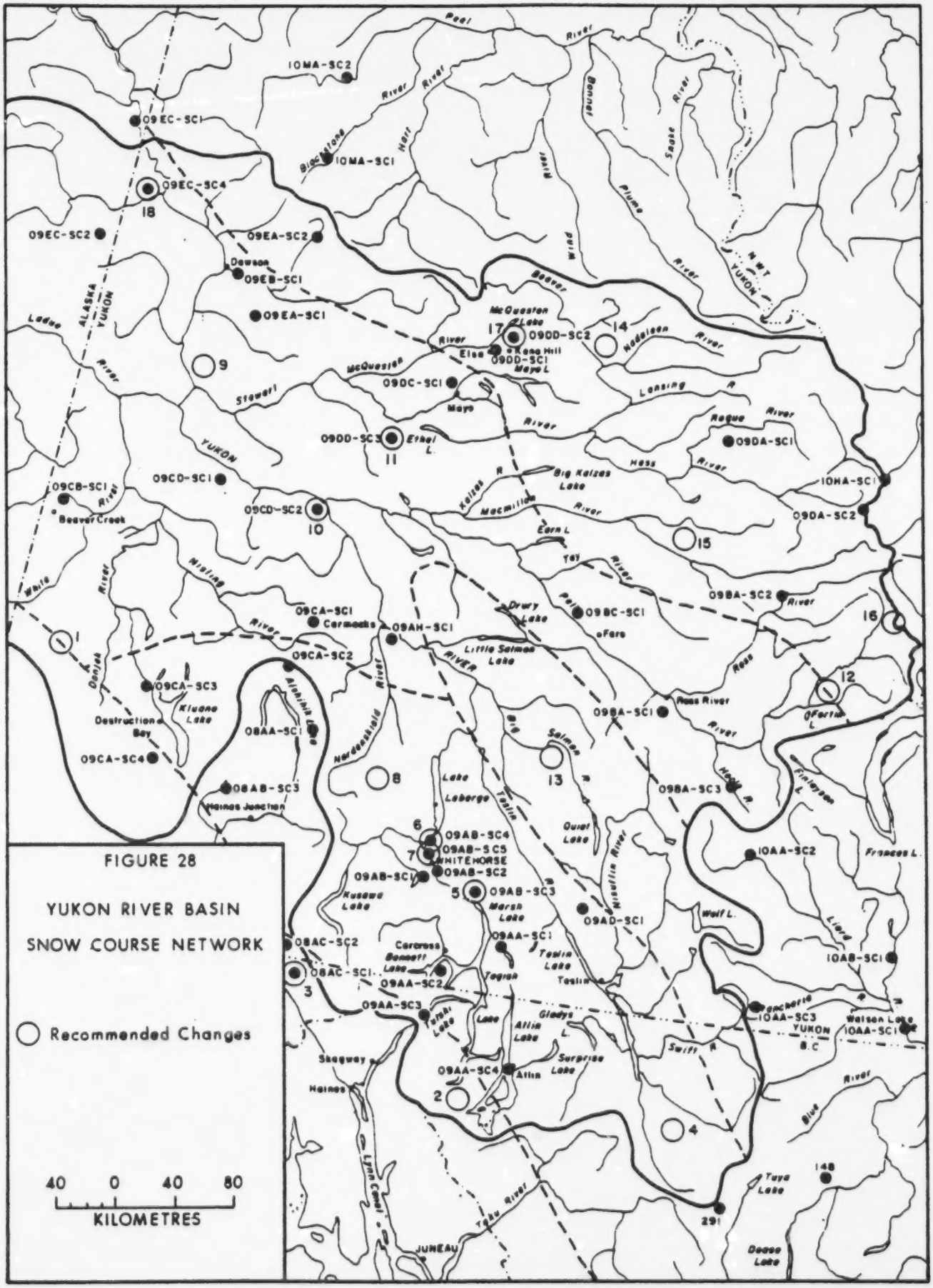


FIGURE 28

YUKON RIVER BASIN

SNOW COURSE NETWORK

○ Recommended Changes

40 0 40 80

KILOMETRES

The study objectives were achieved utilizing both qualitative and quantitative techniques. The former approach represented a subjective evaluation which included the assessment of the spatial distribution of stations with respect to physiographic and climatic characteristics and the sphere of influence of the particular element under consideration. Present and future site specific needs were assessed through the consideration of potential major developments, including hydroelectric and mining developments, linear facilities and recreation. Specifically, these objectives were achieved through a review of existing studies and consideration of agency policy and mandates, a summary of the history of network development, a user survey through the means of a questionnaire, and through telephone conversations and meetings with key representatives of the various data collection networks and user groups.

The latter approach represented a statistical assessment based on a regionalization procedure. The objective was to define regions within which the distribution of the elements under consideration is homogeneous and representative of that region. This was achieved by utilizing several multivariate statistical techniques but in the end was applicable only to the data collection network operated by WSC.

A cluster analysis was initially carried out using data from relatively long term stations with the intent of identifying rudimentary groupings. Two relatively distinct groups and one transitional one were derived using input parameters which consisted of unit low and peak flow values and a timing parameter. These groups, which represent the Coast Mountains, Interior Yukon and St. Elias Mountains, were comparable in part to those defined during a physical regionalization exercise which consisted of the simultaneous comparison of physiographic and climatic regions and patterns of mean annual runoff. Insufficient data exists in the northen and eastern portions of the basin for statistical definition; hence, these areas were included in the Interior group.

Multiple discriminant analysis was then used to define the zones by amending or verifying the boundaries. The previously assigned long term stations acted as training groups to classify stations with smaller data sets, thereby utilizing a greater number of stations. The distinction between the two mountain zones became less defined. Therefore, these were combined to yield the Western Mountains and Interior regions which represent distinct hydrologic units based on

the premise that regions subject to similar climatic and physiographic variation should likewise yield uniform hydrologic responses. These hydrologic zones will provide the basis for transferring information from gauged to ungauged areas.

A correlation analysis using historical monthly discharge data was then performed on all stations within the established regions with the intent of identifying pairs of stations which were highly interrelated. These were identified, and it is recommended that these be further examined over a complete range of flows.

It was not possible to apply a similar statistical approach to the other data collection networks. The information provided by the hydrometric network operated by DIAND was found to be incompatible with similar information collected by WSC. This is primarily due to the relatively short record lengths and the seasonal nature of the DIAND operation. The network was evaluated using the hydrologic regions established using a WSC data.

Due to a relatively sparse data base and the extreme variability of climatic parameters which is even more enhanced by the variation of these parameters with elevation, a statistical assessment of the meteorological network was determined to be inappropriate. Instead, a minimum spacing criteria recommended by the World Meteorological Organization and modified by AES to meet Canadian needs was used.

For much the same reasons, and in addition the relatively short record lengths due to the recency of the snow course network, a statistical analysis was not attempted. The network was assessed subjectively with respect to baseline and site specific coverage using climatic regions as defined by Wahl (1983) as the basis for the evlauation. It is recommended, however, that a correlation analysis be one of the tools utilized in assessing the utility of questionable stations.

Specific recommendations have been summarized above. Generally, all peripheral regions of the basin have deficiencies in all networks with respect to baseline requirements. The headwater areas of the upper Yukon and Teslin basins and the middle to upper Pelly and Stewart basins have deficiencies with respect to both baseline and site specific requirements.

The hydrometric network operated by WSC provides reasonable baseline coverage of intermediate and large watersheds within the basin. Coverage of small basins is less than adequate, however, and recommendations have been made to satisfy this deficiency using sites currently monitored by DIAND. In order to maintain consistent standards it is recommended that the monitoring of baseline and other long term stations be carried out exclusively by WSC. DIAND would

continue to monitor flows from small basins which are required for short term site specific purposes. Recommendations have been made regarding both the meteorological and climatological components of the overall meteorological program. The former, which is used primarily for weather forecasting purposes, was assessed using AES spacing criteria. However, it is noted that these are intended for comparison purposes only. For this reason, however, the recommendations may be inappropriate since they concern primarily unpopulated areas.

The climatological network and the snow course network were assessed primarily from a water management point of view, though other uses were considered. Generally, these networks are deficient in the higher elevations of the basin. The majority of the climate stations are situated in valley bottoms where observers are readily available; however, the information provided by these stations is not generally representative of the watershed. To obtain higher elevation information remote stations are required. The annual maintenance costs of these are high due to their inaccessible locations. Though costs are not directly considered, an attempt was made to optimize the location of individual stations in such a way as to maximize data utility and transferability. Integration of networks is also considered from a data use point of view, though this was not one of the primary objectives of the study. Recommendations with respect to collocation were made in a few cases, primarily where a real time data capability was recommended.

It is believed that the proposed changes to the existing networks, if implemented, will improve the utility and effectiveness of the networks for providing both long term baseline information and site specific information for proposed developments and current operational needs. The various component networks should be reassessed and updated periodically. Proposed new developments or shifting priorities will affect the need for associated hydrometeorological information. New techniques will be developed which have different data requirements, and the information provided by a particular component network may result in the lack of a need for information from another network. In addition, stations which are found to duplicate information as record lengths increase or likewise no longer provide useful data should be discontinued.

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APPENDIX

YUKON RIVER BASIN STUDY HYDROMETEOROLOGICAL NETWORK
ASSESSMENT QUESTIONNAIRE

Agency Name, address and phone:

Contact:

Which of the following data types do you utilize? (if more than one, what proportion of time in relation to other data types (percent)?

WSC hydrometric	_____	_____%
AES climatic	_____	_____%
BC/DIAND Snow Survey	_____	_____%
DIAND Small Streams	_____	_____%

Please indicate which of the following project types you use this data for:

	Investigation	Design	Operation
1. Hydroelectric	_____	_____	_____
2. Water Use (industrial)	_____	_____	_____
3. Water Use (residential and municipal)	_____	_____	_____
4. Water Use (irrigation	_____	_____	_____
5. Navigation	_____	_____	_____
6. Flood control (storage)	_____	_____	_____
7. Flood control (dike, diversion)	_____	_____	_____

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	Investigation	Design	Operation
8. Flood forecasting	_____	_____	_____
9. Storm-water drainage	_____	_____	_____
10. Stream crossing	_____	_____	_____
11. Instream demands	_____	_____	_____
12. Water quality assessment	_____	_____	_____
13. Recreation	_____	_____	_____
14. Planning and Resource Evaluation	_____	_____	_____
15. Wildlife Habitat Assessment	_____	_____	_____
16. Other (please specify)	_____	_____	_____

Please list your specific uses (i.e. flood frequency analyses, reservoir inflow projections, etc.)

Are the data networks used by your agency adequate?

What time base do you feel is necessary?

Do you see any obvious gaps or deficiencies?

Do you feel certain stations provide redundant information or otherwise are not necessary?

Comments?